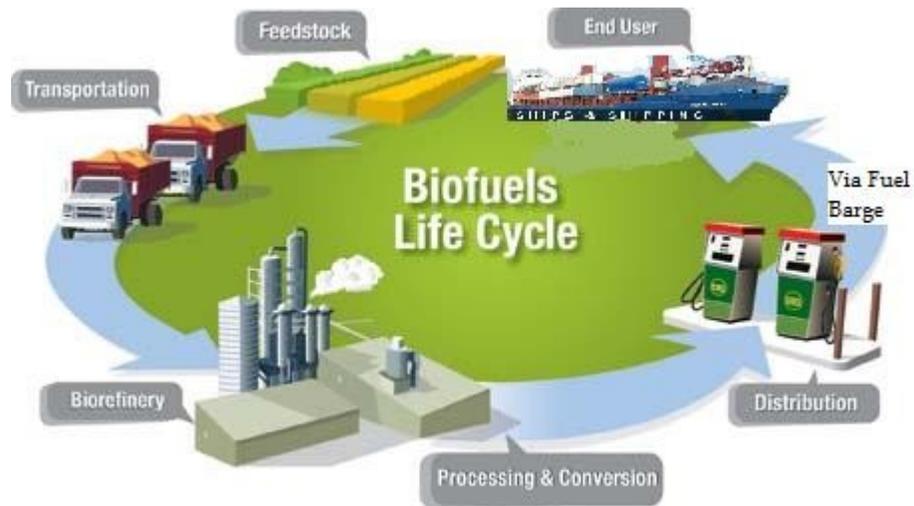


The Use of Biodiesel Fuels in the U.S. Marine Industry



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Prepared For:



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I Executive Summary

The U.S. Maritime Administration (MARAD), the federal agency that promotes and oversees programs for waterborne transportation of goods and passengers, has recently realigned many of its functions, to revitalize its role as an industry facilitator, and to bring greater focus to the areas of safety, environment and energy. MARAD's mission includes oceangoing ships – cargo and passenger, and coastal and intra-coastal vessels. It also maintains the Ready Reserve Fleet that can be activated for wartime surge sealift. The onus on global warming in recent years combined with the current Administration's call for drastically reducing dependence on foreign oil and fossil fuels have brought into focus alternative forms of energy and renewable energy solutions that have a corresponding positive impact on air emissions. By a memorandum dated May 5, 2009, the President formed the Biofuels Interagency Working Group (IWG) with high-level U.S. Department of Agriculture (USDA), Department of Energy (DOE), and Environmental Protection Agency (EPA) participation. On February 3, 2010, the IWG released its first report – “Growing America's Fuel”. The report, authored by group co-chairs, Secretaries Vilsack and Chu, and Administrator Jackson, lays out a strategy to advance the development and commercialization of a sustainable biofuels industry to meet or exceed the nation's biofuels targets. According to this report, “advanced next generation biofuels will be one of the nation's most important industries in the 21st century.”

With U.S. commercial consumption of marine diesel currently estimated at approximately 2.25 billion gallons per year, marine use of biodiesel would be a potentially large market within the context of a future national biodiesel industry. Biodiesels are one form of alternative fuels which are increasingly available commercially and have proven benefits in some applications; however, the marine environment offers unique challenges. This Study reviews the current and potential use of biodiesel for commercial marine applications, while examining the potential benefits and problems associated with its use.

The Study reviews previous studies and current information relative to both surface and marine use of biodiesel with the ensuing challenges regarding logistics, availability, economics, stability and handling of the fuel; and federal/state laws, credits, and mandates relative to both the use of biodiesel fuel, and emissions. Direct discussions were held with marine engine manufacturers and users of biodiesel fuels in both marine and surface applications. Information for surface (non-marine) applications of biodiesel fuel is included and referenced in this study, as there has been sparse evidence of sustained use among the commercial marine community. Relatively few studies have been conducted for actual large scale commercial marine applications. Those that have been conducted, such as by the Washington State Ferry System and Celebrity Cruise Lines/Royal Caribbean Cruise Lines, are covered in this report.

Biodiesel production, use and acceptance in the U.S. increased dramatically in the past few years for both on-road and off-road use. While the use of biodiesel has performed relatively well for these applications, there are no current or pending specifications or large scale fueling facilities for marine grade biodiesel. Biodiesel use for marine applications has so far involved

the use of custom specifications and blending procedures. The American Society of Testing and Materials (ASTM) recently approved two new specifications which could affect supply lines. The first is ASTM D-975-09, which now permits the addition of up to 5% biofuel to the diesel. This is the basic diesel specification used in the U.S. for commercial applications. In addition, ASTM 7647-09 has been approved for bio-blends B6 to B20 (6 to 20% biofuel) and is now being accepted for Government purchase of B20 grade biodiesel for on-road use. Neither of these “blends” are currently approved for use as marine fuel, but could potentially find their way into marine use as more users purchase commercial grade diesel to meet Federal, State, or local mandates for emissions, and renewable fuel use.

The characteristics of biodiesel potentially affecting safety in marine applications are of paramount concern. These concerns include inconsistent quality, lack of marine standards, and impact on engine seals, engine manufacturer’s warranties, disadvantageous hydrophilic properties, cold weather flow drawbacks, and the ability to remain stable in a marine environment over a period of time.

The commercial cost of biodiesel blended fuel, up to 20% blend, is approximately the same as petroleum diesel on an energy equivalent basis. The cost of pure biodiesel is approximately 25% higher than petroleum diesel using the same basis, and applying the currently applicable federal credit for the use of biofuel. The cost of changing from commercially purchased marine-use diesel to biodiesel is high, for a marine environment. The one-time costs associated with tank cleaning, engine and fuel system equipment seal change-outs, testing, filter replacements, repairs, quality assurance precautions and additional contracting and delivery costs can be substantial. Power reduction is also observed with biodiesel use - blends of 20% biodiesel result in 3% reduction of power, and up to 10% reduction in power is seen for pure biodiesel (B100). This has the potential of impacting marine operations.

Biodiesel will reduce the emissions of SO_x since it contains no sulfur. It may, however, increase NO_x emissions, depending on the type, design and age of engines being used. ISO, MARPOL, EPA and various state regulations have mandated major changes in marine fuel and engines to reduce emissions. These rules require the use of Low or Ultra Low Sulfur (15ppm) fuel by 2015. The change in fuel will result in reduced SO_x and particle emissions (which will meet the proposed limits) and may reduce, or eliminate the need/interest to use or blend biofuel for marine applications unless mandated, or if the economic picture changes.

It is not evident that the use of biofuels (B6 to B100) for oceangoing marine applications will increase over current levels, unless mandated or substantially incentivized, and there are standards in place for marine use. There may be exceptions such as the use of biodiesel in marine generators and boilers, while in port, to meet national and local “Port Clean Air Standards”, which are currently being rewritten. Lower level blends (up to 5% or B5) of biodiesel, by virtue of their standardization by ASTM, and availability are already joining mainstream diesel supply and distribution systems, and may find increasing use in the recreational boating industry.

II. Biodiesel Basics

- **General/Definitions**

Biodiesel: The Department of Energy’s Alternative Fuels Data Center describes Biodiesel as follows:

“Biodiesel is a domestically produced, renewable fuel that can be manufactured from vegetable oils, animal fats, or recycled restaurant greases.” Biodiesel is the main fuel addressed in this report as nearly all commercial marine use involves the operation of “compression ignition” engines (diesels), boilers and gas turbines. All biodiesel must meet ASTM, international, or commercial standards as described in the report. These standards do not permit the addition of ethanol.

Bio-fuel: Bio-fuel is a broad category of fuels included under the umbrella of the Biomass Program and can assume liquid or gaseous form. Biodiesel is a sub-category of Biofuel. Other fuels in the biofuel category include those derived from ethanol and second generation regenerative fuels. The term “biofuel” has sometimes been interchangeably used with biodiesel in this report to maintain continuity with the references used.

E-Diesel: The Department of Energy describes E-Diesel as follows:

“E-Diesel is a fuel that uses additives in order to allow blending of ethanol with diesel. It includes ethanol blends of 7.7% to 15% and up to 5% special additives that prevent the ethanol and diesel from separating at very low temperatures or if water contamination occurs. There is a slight increase in operating costs due to a slight (7-10%) mileage decrease with E-diesel use.” E-Diesel was previously included in the DOE “Biomass Program”, but after a review in 2007 it appears to have been dropped as a priority. A review of current programs has found no mention of E-Diesel and it is not addressed further in this report.

Most biodiesel in the U.S. is derived primarily from soybean oil, and is referred to as Soy Methyl Ester (SME). In Europe, the most common biodiesel is derived from rapeseed oil, and is referred to as Rapeseed Methyl Ester (RME). U.S. soybean-derived biodiesel will not usually meet the European standard for stability. Palm oil based biodiesel is gaining wide acceptance because of the economy of production. Animal fats have been used to produce biodiesel fuels and due to the recent increase in the price of soy oil, they are being more seriously considered. Animal fat-based biodiesel has different properties than vegetable oil-based biodiesel and normally have poor cold flow and stability properties. Animal fat-based biodiesel is not permitted by the federal specification for B20, but is permitted in the latest ASTM specifications for commercial grade diesel fuel.

Biodiesel can be used in several ways. 1% to 2% may be used as a lubricity additive, which is important for ultra low sulfur diesel fuels (ULSD), less than 15 ppm sulfur, which may have poor lubrication properties. Blends of 5% (B5) and 20% (B20) biodiesel, with the remainder being No. 1 or No. 2 diesel, kerosene, Jet A, JP8, or other distillate fuel, are the most

used blends in the U.S. The 20% (B20) blend is the primary blend used for surface applications, because it balances properties, performance, emission benefits and costs.

B20 is also the minimum blend allowed for Energy Policy Act of 1992 compliance. Higher blends (including 100% biodiesel) require special handling and fuel management and may require equipment modifications, such as the use of heaters, or the changing of seals and gaskets that come in contact with the fuel. The cruise line industry prefers to use neat (100%) palm oil-based biodiesel due to certain properties and economic benefits. Palm oil biodiesel does not always meet U.S. or EU standards for properties or emissions.

Other countries and organizations have created different specifications for biodiesel. These specifications are based in part on the use of locally available feed stocks and do not necessarily meet the U.S. standard for B100, or any blends. The U.S. standard for B100, likewise, does not necessarily meet foreign standards. There is no unified standard for biodiesel. There are, however recognized universal standards for petroleum fuels. ASTM, ISO, and NATO standards are some examples.

All biodiesel fuels are produced by a process called *transesterification*, in which various oils (triglycerides) are converted to methyl esters through a chemical reaction where most glycerols and water are removed as undesirable products. Depending on the feedstock and the process used to produce the fuel, B100 fuels should meet the requirements of either ASTM D 6751 or an approved European specification, such as DIN 51606 or EN14214.

The properties of finished biodiesel depend heavily on the feedstock used. These properties can include Cetane number, cold flow, and stability. Biodiesel can be produced commercially from a variety of oils and fats including, but not limited to: Animal fats - edible tallow, inedible tallow, and all other variations of tallow, lard, white grease, poultry fats and fish oils; Vegetable oils - soy, canola, sunflower, cottonseed, mustard, palm, coconut, peanut, olive, sesame, and safflower, recycled greases, used cooking oils, and restaurant frying oils.

What makes each of these feedstocks different is that they are made of different proportions of saturated, monounsaturated and polyunsaturated fatty acids. A “perfect” biodiesel would be made only from monounsaturated fatty acids. Figure 1 shows the properties of the most common feedstock used to produce biodiesel.

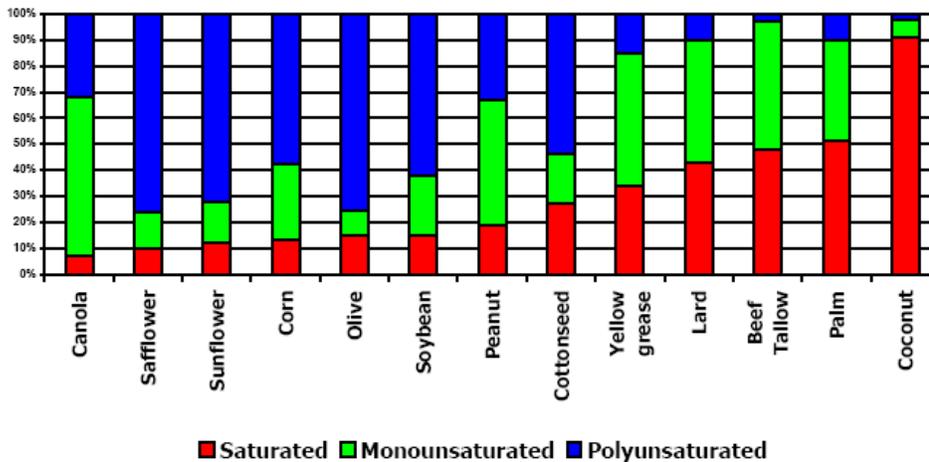


Figure 1. Feed Stock Properties [11].

• Basic Biodiesel Process

There are several methods such as the Batch, Supercritical and Ultrasonic-Reactor methods that are used for producing biodiesel depending on the quantity needed and the budget available for setting up the plant. Research is underway for the Microwave method which will use commercial microwave ovens to produce the heat needed for large scale production. An understanding of the basic Batch process provides an insight into all these methods, and is briefly explained below.

Biodiesel production is a combination of chemical reactions, the most basic of which is called *transesterification*. Fat and oil derivatives from animals and plants are typically made of triglycerides which are esters of free fatty acids along with glycerol. In the transesterification process, the glycerol is deprotonated with a base, such as ethanol or methanol to make it a stronger nucleophile, producing methyl esters (biodiesel) in the process. Heat and a catalyst are used to help the reaction proceed more quickly.

Sometimes free fatty acids (FFAs) may pose a problem in the process. A FFA is one that has already separated from the glycerol molecule. This is usually the result of the oil breaking down after many cycles of use, as with used vegetable oil. The consequence is:

- More catalyst will need to be used leading to higher cost.
- Soap (fatty acid salt) is formed, making washing the finished product more difficult.
- Water is formed which will retard the main reaction.
- The FFAs are not converted into fuel, reducing the yield.

The basic process to find the percent of FFA is called *titration*, which also determines what quantity of catalyst, such as sodium hydroxide (NaOH) is needed for a particular batch. When the oil has less than 2.5% FFA, the problems listed above are negligible and will need transesterification only. When FFA content is higher, there are several options available. The easiest is to mix the high FFA oil with low FFA oil. This will work for an occasional high FFA batch. Other options require esterification (two-stage process), or intentionally making a removable and preferably, usable product such as soap. This is done by use of Methanol or some other catalyst.

Figure 2 shows a flow chart of the processes described above.

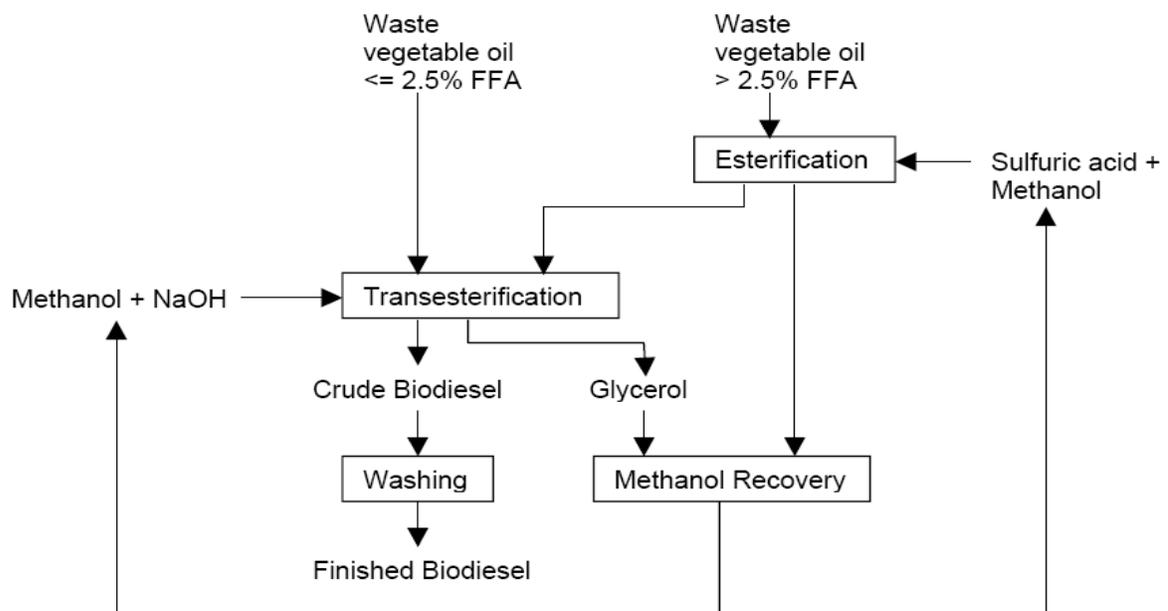


Figure 2. Biodiesel Process Flowchart [41]

- **Blending**

All blending specifications are based on the volume content of the blended fuel. B5 is therefore 5% by volume of neat (100%) biodiesel and 95% petroleum diesel. All other blends are calculated in the same manner.

There are two types of blending procedures currently in use, “Splash Blending” and “In-line” or “Manifold Blending”. Splash blending occurs where a specific volume of neat (100%) volume of bio is added to a tank (or barge) and petroleum fuel is then added from either the top or bottom, to produce the desired blend mixture. Until recently, this has been the preferred method to insure the proper blend mixture with the relatively small amounts of biodiesel being ordered. In-line blending has been used in the past, but encountered problems with quality

control due to the equipment used. More recently, approval of ASTM D975-09 has allowed for B5 blends, and several states have mandated the use of biodiesel blends. This has resulted in initiatives to install more sophisticated handling, monitoring and storage equipment. Most of the details of these initiatives are proprietary, but at least one west coast supplier is in the process of installing an 80K barrel storage tank for B5 to meet state mandates to supply biodiesel blends throughout the state. This facility will have heated and insulated supply and delivery lines, along with a humidity controlled and insulated storage tank. It will be used for delivery to truck transportation, for further delivery to service stations or marine applications.

- **B100**

B100 has physical and chemical properties similar to petroleum-based diesel, but also has several drawbacks. It is not normally used as a stand-alone fuel due to the special handling and use requirements it imposes. B100 is an extremely good solvent and may loosen or dissolve sediments in fuel tanks and fuel systems left by conventional diesel fuel over time.

The Pour Point is the cold temperature at which the fuel begins to gel, and marks the limit at which the fuel can be pumped. Cloud Point is the cold temperature at which wax crystals first begin to form in the fuel. Wax crystals will clog fuel filter elements and starve the engine for fuel. B100 gels at a higher temperature than most conventional diesel fuel and starts to cloud at between 35°F and 60°F. Heated fuel lines and tanks may be needed even in moderate climates. As B100 begins to gel, the viscosity begins to rise to higher levels than most diesel fuel. This can cause increased stress on fuel pumps and fuel injection systems. This is the main reason that engine manufacturers and fuel system component manufacturers currently will not warranty equipment produced prior to 2006 for biodiesel blends over 5%, with very few exceptions.

B100 is not compatible with some hoses and gaskets. B100 may soften and degrade certain types of rubber compounds found in hoses and gaskets and may cause them to leak and become degraded to the point they crumble and become useless. This could cause a fuel spill on a hot engine – which would be an extremely dangerous situation in a marine environment and under conditions in which vessels normally operate. This same property could result in fuel pump failure, or in filter clogging as the hose material wears away. Engines manufactured before approximately 1993 are likely to contain seals, gaskets and other components that will be affected by biodiesel blends of B20 and above.

B100 is not compatible with some metals and plastics. All biodiesel blends will form high sediment levels and fuel degradation if contacted for long periods of time with copper or copper containing metals, or with lead, tin, or zinc. These materials may be contained in marine fuel transfer equipment such as centrifugal purifiers. These high sediment levels may cause filter clogging. B100 may also permeate some typical types of plastics (polyethylene, polypropylene) over time and these should not be used for storing B100 [11] [18]. No attempt was made to investigate the fuel system specifications for oceangoing Navy or commercial vessels, or for the numerous types of inland and near-shore commercial vessels, but it must be assumed that some of them employ copper fuel lines.

B100 contains approximately 11% oxygen by weight, as well as a slightly higher Cetane number than No. 2 diesel. This chemistry provides for a more complete combustion and a reduction in most emissions when compared to pure petroleum diesel, but also creates problems regarding long-term storage (oxidation of the fuel) and microbe growth.

B100 does not have full ASTM consensus as a stand-alone fuel specification and is only recognized by a select few equipment manufacturers. It is typically used as a blend stock with traditional petroleum-based diesel fuel.

- **B20**

ASTM specifications for finished biodiesel blends up to B20 were approved in 2009 under ASTM 7467-09 for blends B6 to B20 (6% to 20%). The B20 specification previously used for government procurement is government specification A-A-59693A. The General Services Administration (GSA) has authorized the use of this Commercial Item Description (CID) for all federal agencies. It is also similar to the specification used by the Defense Logistics Agency (DLA) to purchase biodiesel for on-road, non-tactical diesel fuel-consuming vehicles. DLA/DESC recently has approved the use of ASTM-7467-09 specifying that the biodiesel content must be 20% +/- 1% and also attaches an additional requirement (not included in the base specification) that the 20% biodiesel product be derived from “virgin vegetable oil blend stock and/or yellow grease blend stock conforming to the requirements of ASTM D 6751”. B20 blends not meeting this specification may have a higher viscosity, which can cause added stress on the fuel system and inadequate fuel atomization that can result in poor engine performance and injector coking. B20 meeting this specification can generally be used interchangeably with diesel fuel for normal usage, as long as the biodiesel blend stock meets the requirements of ASTM D 6751 and the cold flow properties of the blend are adequate for the geography and time of year the fuel will be used. Most engine and fuel system manufacturers will not provide warranties for equipment used with biodiesel blends of over 5%.

The problems which were described above for B100 are also evident when using B20, but to a lesser degree. B20 blended fuel meeting A-A-59693A and/or ASTM 7467-09 is being widely used for on-road vehicles with good results.

- **B5**

B5 meeting ASTM D 975-09 for Diesel Fuel does not appear to present any problems with economy, performance, or maintenance when used in land transportation. Biodiesel blends (B5) have not been extensively tested for marine applications, and there are no commercial or military specifications available to order a B5 blend of biodiesel fuel for marine applications.

III Directives, Laws and Regulations

There are a variety of directives, laws, regulations, incentives and mandates that apply for the use of biodiesel fuels in the U.S. Information is included here to show the various initiatives which may or will result in the eventual inclusion of biofuels into the common fuel distribution system. The rules are constantly being revised, renewed and rewritten. Shown below are the current and proposed issues which apply to the marine use of biodiesel. (Additional rules are included in section VI "Emissions" of this Report.) They are divided into the following categories:

- **International**
- **Federal U.S.**
- **State U.S.**

International:

MARPOL (The International Convention for the Prevention of Pollution from Ships) - The 2008 Amendments

Revised Annex VI adopted October 2008: MEPC.176 (58) Amendments to the Annex of the Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (Revised MARPOL Annex VI).

October 2008 MARPOL Amendments - Revised Annex VI

Amendments to the MARPOL Annex VI regulations to reduce harmful emissions from ships even further:

The main changes to MARPOL Annex VI will see a progressive reduction in sulfur oxide (SO_x) emissions from ships, with the global sulfur cap reduced initially to 3.50% (from the current 4.50%), effective from January 1, 2012; then progressively to 0.50%, effective from January 1, 2020, subject to a feasibility review to be completed no later than 2018.

The limits applicable in Sulfur Emission Control Areas (SECAs) will be reduced to 1.00%, beginning on July 1, 2010 (from the current 1.50%); being further reduced to 0.10%, effective from January 1, 2015.

Progressive reductions in nitrogen oxide (NO_x) emissions from marine engines were also agreed to, with the most stringent controls on so-called "Tier III" engines, i.e. those installed on ships constructed on or after January 1, 2016, operating in Emission Control Areas (ECA).

The revised Annex VI will allow for an ECA to be designated for SOx and particulate matter, or NOx, or all three types of emissions from ships, subject to a proposal from a Party or Parties to the Annex, which would be considered for adoption by the Organization, if supported by a demonstrated need to prevent, reduce and control one or all three of those emissions from ships.

Federal: U.S.

The U.S. is aggressively supporting and mandating the use of alternative fuels. Biodiesel is one subset under the definition of “alternative fuels”. There are approximately 46 Incentives, Laws, Regulations and Programs and proposals pertaining to alternative fuels that are currently enacted. A summary of those that apply to the production, distribution and use of biodiesel fuels, within the scope of this study are as follows:

1. The overarching U.S. mandate, H.R. 1424, the “**Emergency Economic Stabilization Act**” was signed into law on October 3, 2008. It extends the income tax credits, blenders excise tax credit and the small producer tax credit that make up the biodiesel tax incentive for one year, through December 31, 2009. The incentive was set to expire on December 31, 2009, but was expected to be extended. (This credit had not been extended as of this writing.) The Act further provides that all biodiesel, regardless of feedstock used to produce the fuel, qualifies for the \$1 per gallon biodiesel incentive. Currently, biodiesel produced from yellow grease is eligible for 50 cents per gallon tax incentive. The effective date for this change in H.R. 1424 (P.L. 110-343) was January 1, 2009.

The Act also closes the so-called “splash and dash” loophole. Splash and dash is where foreign finished fuel is sent to the U.S., splash blended to claim the tax incentive and then shipped to a third country for final use. There is clearly no energy or tax policy justification for these transactions, and it has been long-standing National Biodiesel Board (NBB) policy that the splash and dash loophole should be closed. The legislation approved by the Senate provides that effective May 15, 2008, fuel produced outside the U.S. for use outside the U.S. does not qualify for the biodiesel tax incentive, and defines the \$1 renewable diesel tax incentive to exclude co-processed renewable diesel. In H.R. 1424 (P.L. 110-343), this change was effective upon date of enactment on October 3, 2008.

2. **Alternative Fuel Excise Tax Credit:** A tax incentive is available for alternative fuel that is sold for use or used as a fuel to operate a motor vehicle. A tax credit in the amount of \$0.50 per gallon is available for the following alternative fuels: compressed natural gas (based on 121 cubic feet), liquefied natural gas, liquefied petroleum gas, liquefied hydrogen, P-Series fuel*, liquid fuel derived from coal through the Fischer-Tropsch process, and compressed or liquefied gas derived

* Note: P-Series fuel is a blend of natural gas liquids (pentanes plus), ethanol, and the biomass-derived co-solvent smethyltetrahydrofuran (MeTHF). They are clear, colorless, 89-93 octane, liquid blends.

from biomass. For an entity to be eligible to claim the credit they must be liable for reporting and paying the federal excise tax on the sale or use of the fuel in a motor vehicle. Tax exempt entities such as state and local governments that dispense qualified fuel from an on-site fueling station for use in vehicles qualify for the incentive. All eligible entities must be registered with the Internal Revenue Service (IRS). The incentive must first be taken as a credit against the entity's alternative fuel tax liability; any excess over this fuel tax liability may be claimed as a direct payment from the IRS. The tax credit is not allowed if an incentive for the same alternative fuel is also determined under the rules for the ethanol or biodiesel tax credits. Under current law, this incentive expired on December 31, 2009 (was expected to be extended at time of this writing), except in the case of the credit for liquefied hydrogen, which is set to expire on September 30, 2014.

- 3. Energy Improvement and Extension Act of 2008:** The Energy Improvement and Extension Act of 2008 is Division B of the Emergency Economic Stabilization Act, signed into law on October 3, 2008. Title II of Division B of the law applies to the Clean Cities portfolio areas (alternative fuels, advanced vehicles, idle reduction, etc.). Section 202 amends the existing biodiesel mixture and agri-biodiesel production tax credits by extending the tax credits for one year through December 31, 2009, and allowing all biodiesel, regardless of feedstock to qualify for the \$1.00 per gallon mixture incentive (with the exception of co-processed renewable diesel), and adds camelina as a qualified feedstock for agri-biodiesel production.
- 4. Alternative Fuel Infrastructure Tax Credit:** A tax credit is available for the cost of installing alternative fueling equipment placed into service after December 31, 2005. Qualified alternative fuels are natural gas, liquefied petroleum gas, hydrogen, electricity, E85, or diesel fuel blends containing a minimum of 20% biodiesel. The credit amount is up to 30% of the cost, not to exceed \$30,000, for equipment placed into service before January 1, 2009. The credit amount is up to 50% not to exceed \$50,000, for equipment placed into service on or after January 1, 2009. Fueling station owners who install qualified equipment at multiple sites are allowed to use the credit towards each location. Consumers who purchase residential fueling equipment may receive a tax credit of up to \$1,000, which increases to \$2,000 for equipment placed into service after December 31, 2008. The maximum credit amount for hydrogen fueling equipment placed into service after December 31, 2008, and before January 1, 2015, is \$200,000. The credit expires December 31, 2010, for all other eligible fuel types.
- 5. Biodiesel Income Tax Credit:** A taxpayer that delivers pure, unblended biodiesel (B100) into the tank of a vehicle, or uses B100 as an on-road fuel in their trade or business, may be eligible for an incentive in the amount of \$1.00 per gallon of biodiesel, agri-biodiesel, or renewable diesel. If the biodiesel was sold at retail, only the person that sold the fuel and placed it into the tank of the vehicle

is eligible for the tax credit. The incentive is allowed as a credit against the taxpayer's income tax liability. Claims must include a copy of the certificate from the registered biodiesel producer or importer that: identifies the product; specifies the product's biodiesel, agri-diesel, and/or renewable diesel content; confirms that the product is properly registered as a fuel with the (EPA); and confirms that the product meets the requirements of ASTM specification D6751. Renewable diesel is defined as liquid fuel derived from biomass that meets EPA's fuel registration requirements and ASTM specifications D975 or D396; the definition of renewable diesel does not include any fuel derived from co-processing biomass with a feedstock that is not biomass. Under current law, this incentive expired on December 31, 2009 but was expected to be extended at time of this writing.

- 6. Biodiesel Mixture Excise Tax Credit:** A biodiesel blender that is registered with the Internal Revenue Service (IRS) may be eligible for a tax incentive in the amount of \$1.00 per gallon of pure biodiesel, agri-biodiesel, or renewable diesel blended with petroleum diesel to produce a mixture containing at least 0.1% diesel fuel. Only blenders that have produced and sold or used the qualified biodiesel mixture as a fuel in their trade or business are eligible for the tax credit. The incentive must first be taken as a credit against the blender's fuel tax liability; any excess over this tax liability may be claimed as a direct payment from the IRS. Claims must include a copy of the certificate from the registered biodiesel producer or importer that: identifies the product; specifies the product's biodiesel, agri-biodiesel, and/or renewable diesel content; confirms that the product is properly registered as a fuel with the EPA; and confirms that the product meets the requirements of ASTM specification D6751. Renewable diesel is defined as liquid fuel derived from biomass that meets EPA's fuel registration requirements and ASTM specifications D975 or D396; the definition of renewable diesel does not include any fuel derived from co-processing biomass with a feedstock that is not biomass. Under current law, this incentive expired on December 31, 2009 but was expected to be extended. Congress is reviewing rules to not permit tax credits for the use of low cost, imported biofuels like palm oil.
- 7. Alternative Fuel Definition:** The following fuels are defined as alternative fuels by the Energy Policy Act (EPA) of 1992: pure methanol, ethanol, and other alcohols; blends of 85% or more of alcohol with gasoline; natural gas and liquid fuels domestically produced from natural gas; liquefied petroleum gas (propane); coal-derived liquid fuels; hydrogen; electricity; pure biodiesel (B100); fuels, other than alcohol, derived from biological materials; and P-Series fuels. In addition, the U.S. Department of Energy (DOE) is authorized to designate other fuels as alternative fuels, provided that the fuel is substantially non-petroleum, yields substantial energy security benefits, and offers substantial environmental benefits.
- 8. Alternative Fuel Definition - Internal Revenue Code:** The Internal Revenue Service (IRS) defines alternative fuels as liquefied petroleum gas, compressed natural gas, liquefied natural gas, liquefied hydrogen, liquid fuel derived from

coal through the Fischer-Tropsch process, liquid hydrocarbons derived from biomass, and P-Series fuels. Biodiesel, ethanol, and renewable diesel are not considered alternative fuels by the IRS. While the term "hydrocarbons" includes liquids that contain oxygen, hydrogen, and carbon and as such "liquid hydrocarbons derived from biomass" includes ethanol, biodiesel, and renewable diesel, the IRS specifically excluded these fuels from the definition. (Reference 26 U.S. Code 6426)

- 9. Alternative Fuel Tax Exemption - Internal Revenue Code:** Alternative fuels used in a manner that the Internal Revenue Service (IRS) deems as non-taxable are exempt from federal fuel taxes. Common non-taxable uses in a motor vehicle are: on a farm for farming purposes; in certain intercity and local buses; in a school bus; exclusive use by a nonprofit educational organization; and exclusive use by a state, political subdivision of a state, or the District of Columbia. This exemption is not available to tax exempt entities that are not liable for excise taxes on transportation fuel.
- 10. Renewable Fuel Standard (RFS) Program:** The national RFS program was developed to increase the volume of renewable fuel that is blended into gasoline and other transportation fuels. As required by the Energy Policy Act of 2005, the U.S. Environmental Protection Agency (EPA) finalized RFS program regulations, effective September 1, 2007. The Energy Independence and Security Act of 2007, signed into law in December 2007, increased and expanded this standard. In 2008, 9 billion gallons of renewable fuel must be used, increasing to 36 billion gallons per year by 2022. Beginning in 2013, a certain percentage of the renewable fuels must be advanced and/or cellulosic based biofuels and biomass-based diesel, pending final rulemaking by EPA. Cellulosic biofuel is defined as any renewable fuel derived from cellulose, hemi cellulose, or lignin, and achieves a 60% greenhouse gas (GHG) emissions reduction. Advanced biofuel is defined as any renewable fuel, other than ethanol derived from corn, derived from renewable biomass, and achieves a 50% Green House Gas (GHG) emissions reduction.

Each year, EPA will determine the Renewable Volume Obligation (RVO) for parties required to participate in the RFS program. This standard is calculated as a percentage, by dividing the amount of renewable fuel (gallons) required by the RFS to be blended into gasoline for a given year by the amount of gasoline/transportation fuel expected to be used during that year. Any party that produces gasoline for use in the U.S., including refiners, importers, and blenders, is considered an obligated party under the RFS program. Parties that do not produce, import, or market fuels within the 48 contiguous states are exempt from the renewable fuel tracking program. Small refineries and refiners are also exempt from the program until 2011. A small refinery is defined as one that processes fewer than 75,000 barrels of crude oil per day, has a total crude capacity of less than 150,000 barrels per day, and employs fewer than 1,500 employees company-wide. All obligated parties are expected to meet their RVO beginning in 2007.

To facilitate and track compliance with the RFS, a producer or importer of renewable fuel must generate Renewable Identification Numbers (RINs) to represent renewable fuels produced or imported by the entity on or after September 1, 2007, assigned by gallon or batch. Assigned RINs are transferred when ownership of a batch of fuel occurs, but not when fuel only changes custody. A trading program is in place to allow obligated parties to comply with the annual RVO requirements through the purchase of RINs. Obligated parties must register with the EPA in order to participate in the trading program. For each calendar year, an obligated party must demonstrate that it has sufficient RINs to cover its RVO. RINs may only be used for compliance purposes in the calendar year they are generated or the following year. Obligated parties must report their ownership of RINs to the EPA's Office of Transportation and Air Quality on a quarterly and annual basis.

11. EPA Program for 2010 and Beyond (Proposed, May 2009). The U.S. Environmental Protection Agency is proposing revisions to the National Renewable Fuel Standard program (commonly known as the RFS program). Proposed rule intends to address changes to the RFS program as required by the Energy Independence and Security Act of 2007 (EISA). The revised statutory requirements establish new specific volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that must be used in transportation fuel each year. The revised statutory requirements also include new definitions and criteria for both renewable fuels and the feedstock used to produce them, including new greenhouse gas (GHG) emission thresholds for renewable fuels. The regulatory requirements for RFS will apply to domestic and foreign producers and importers of renewable fuel.

The current Renewable Fuel Standard program (RFS1) was established under the Energy Policy Act of 2005 (EPAct) which amended the Clean Air Act by establishing the first national renewable fuel standard. The U.S. Congress gave EPA the responsibility to coordinate with the U.S. Department of Energy, the U.S. Department of Agriculture, and stakeholders to design and implement this new program. With the passage of EISA, Congress made several important revisions to these renewable fuel standards that require EPA to promulgate new regulations to implement these changes.

Proposed New Renewable Volume Standards Rule:

This rule proposes to establish the revised annual renewable fuel standard (RFS2) and to make the necessary program modifications as set forth in EISA. Of these modifications, several are significantly notable. First, the volume standard under RFS2 was increased beginning in 2008 from 5.4 billion gallons (Bgal) to 9.0 Bgal of renewable fuels. Thereafter, the required volume continues to increase under

RFS2, eventually reaching 36 B gal of renewable fuels by 2022. The volume requirements proposed for biomass-based diesel in RFS2 are:

| <u>Year</u> | <u>Billion Gallons (Biomass-based Diesel)</u> |
|-------------|---|
| 2010 | 0.65 |
| 2011 | 0.85 |
| 2012 | 1.0 |

After 2012, EPA will determine new requirements for biomass-based diesel. EPA is also proposing to expand EISA requirements to include diesel and non-road fuels. The EISA expanded the program application that would generally cover all transportation fuel. This now includes gasoline and diesel fuel intended for use in highway vehicles and engines, and non-road, locomotive and marine engines. As in RFS1, EPA is proposing that these provisions apply to refiners, blenders, and importers of transportation fuel (with limited flexibilities for small refiners), and that their percentage standards apply to the total amount of gasoline and diesel they produce for such use. They also proposed to use the current definition of motor vehicle, non-road, locomotive, and marine diesel fuel (MVNRLM) to determine the obligated volumes of non-gasoline transportation fuel for this rule.

In April 2009, EPA submitted “Proposal to designate an Emission control Area for Nitrogen Oxides, Sulfur Oxides and Particulate Matter” (EPA-420-H-09-007). This proposal is under review, but could impact the type of fuel used for marine applications in designated areas and ports. See the “Emissions” section of this report for additional information.

- 12. Department of Energy:** The DOE announced on December 04, 2009, the selection of 19 integrated bio-refinery projects to receive up to \$564 million from the “American Recovery and Re-investment Act” to accelerate the construction and operation of pilot, demonstration, and commercial scale facilities. The projects are matched with more than \$700 million in private and non-federal cost-share funds for a total of almost \$1.3 billion.

State: U.S.

Almost all the U.S. states have laws and incentives on their books or in their legislative pipeline pertaining to biofuels. Incentives almost universally take the form of tax credits. Discussed below are some selected state laws and incentives that have already been enacted. These states were selected from those having the most aggressive programs to support the use of biofuels, and are provided as a “snapshot” of state involvement in supporting the use of biofuels to reduce foreign oil imports and reduce green house gas emissions.

Oregon

Biofuels Use Tax Credit

A state resident who purchases gasoline blended with 85% ethanol (E85) or biodiesel blends of at least 99% (B99) for use in an alternative fuel vehicle (AFV) qualifies for an income tax credit of \$0.50 per gallon, up to \$200 for each AFV that is registered in Oregon and owned or leased by the resident. For the purpose of this tax credit, an AFV is a motor vehicle that can operate using E85 or B99. This incentive is applicable until January 1, 2013. (Reference Oregon Revised Statutes 315.465)

Renewable Fuels Mandate

All diesel fuel sold in the state must be blended with 2% biodiesel. The biodiesel blending requirement increases to 5% when the production of biodiesel from state sources reaches a level of at least 15 million gallons on an annualized basis. For the purpose of this mandate, biodiesel is defined as a motor vehicle fuel derived from vegetable oil, animal fat, or other non-petroleum resources, that is designated as B100 and complies with ASTM specification D6751. Beginning January 2, 2012, renewable diesel will qualify as a substitute for biodiesel in the blending requirement.

Renewable Fuels Mandate – Portland

All gasoline sold within the Portland city limits must contain a minimum of 10% ethanol (E10), and diesel fuel must contain a minimum of 5% biodiesel (B5) and must meet ASTM D6751 standards. The diesel blend requirement will increase to 10% biodiesel on July 1, 2010. Fuel vendors must place signage denoting the type of biofuels mixture available for sale. A retailer, who offers a biodiesel blend of 20% (B20) or greater, is exempt from the requirement and is allowed to provide for sale, on the same site or a contiguous site, diesel fuel that does not contain biodiesel. (Reference: Portland Policy Documents ENN-6.02)

Biodiesel Quality Testing Procedures

Each biodiesel or other renewable diesel producer, distributor, or importer must retain the certificate of analysis for each batch or production lot of B100 sold or delivered in the state for at least one year. The Oregon Department of Agriculture (ODA) or authorized agents are permitted to examine these records as necessary. The ODA or authorized agents may perform on-site testing or obtain samples of biodiesel or other renewable diesel from any producer, bulk facility, or retail location that sells, distributes, transports, hauls, delivers, or stores biodiesel or other renewable diesel. The related testing cost is the responsibility of the business from which the sample was obtained. (Reference: Oregon Revised Statutes 646.923)

Exceptions to Biodiesel Mandate

Diesel fuel sold or offered for sale for use by railroad locomotives, marine engines, and home heating is exempt for the requirement to be blended with biodiesel.

California

Alternative Fuel and Vehicle Research and Development Incentives

The “Alternative and Renewable Fuel and Vehicle Technology Program”, established by Assembly Bill 118 and administered by the California Energy Commission, aims to increase the use of alternative and renewable fuels and innovative technologies and develop and improve alternative and renewable low-carbon fuels.

Low Carbon Fuel Standard

California's “Low Carbon Fuel Standard (LCFS) Program” calls for a reduction in the carbon intensity of the state's transportation fuels by a minimum of 10% by 2020. The California Environmental Protection Agency, in coordination with the University of California, the California Energy Commission, and other state agencies, has developed draft regulations. In 2009, the California Air Resources Board approved the LCFS, which establishes standards that fuel producers and importers must meet each year beginning in 2011. Carbon intensity reductions are based on reformulated gasoline mixed with 10%, by volume, corn-derived ethanol, and low-sulfur diesel fuel. The LCFS was slated to go into effect by the end of 2009. (Reference Executive Order S-01-07, 2007, and California Health and Safety Code 38500-38599)

State Biofuels Development Plan

The State of California plans to use biomass resources from agriculture, forestry, and urban wastes to provide transportation fuels and electricity to satisfy California's fuel and energy needs. To increase the use of biomass in fuel production, the state will produce its own biofuels at a minimum of 20% by 2010, 40% by 2020, and 75% by 2050. The California Air Resources Board (CARB) and the California Energy Commission, in conjunction with other agencies, prepared the “Bioenergy Action Plan for California”, which recommended: research and development of commercially viable biofuels production and advanced biomass conversion technologies; evaluation of the potential for biofuels to provide a clean, renewable source for hydrogen fuel.

South Carolina

Biofuels Retail Incentive

Biodiesel retailers are eligible for a \$0.25 incentive payment for each gallon of pure biodiesel (B100) sold, provided that the resulting blends contain at least 2% biodiesel (B2). These incentives apply only to fuel sold before July 1, 2012. Biodiesel fuel is defined as a fuel

for motor vehicle diesel engines comprised of vegetable oils or animal fats and meeting ASTM specifications D6751 or D975. (Reference [South Carolina Code of Laws 12-63-20](#))

Biofuels Production Tax Credit

Qualified corn-based ethanol and soy-based biodiesel producers are eligible for an income tax credit of \$0.20 per gallon of fuel produced for taxable years beginning after 2006 and before 2017. Producers using feedstock other than corn or soy oil are eligible for \$0.30 per gallon tax credit. An eligible production facility must be operating at a production rate of at least 25% of its name plate design capacity and must maintain that production rate for at least six months, before denaturing, on or before December 31, 2011. The credit is allowed for up to 60 months beginning with the first month for which the facility is eligible to receive the credit and ending not later than December 31, 2016. Beginning January 1, 2017, the credit changes to \$0.075 per gallon of fuel produced. (Reference [South Carolina Code of Laws 12-6-3600](#))

Biofuels Research and Development Tax Credit

For taxable years beginning after 2007 and ending before 2012, an income tax credit is available for up to 25% of qualified research and development expenditures, which include developing feedstock and production processes for cellulosic ethanol and algae-derived biodiesel. Cellulosic ethanol is defined as fuel from ligno-cellulosic materials, including wood chips, corn stover, and switch grass. (Reference [South Carolina Code of Laws 12-6-3631](#))

State Agency Biodiesel Blend Mandate

All state-owned diesel fueling facilities must provide fuel containing at least 5% biodiesel (B5) in all diesel pumps. (Reference [South Carolina Code of Laws 12-63-30](#))

Alternative Fuel Tax

All fuels, including alternative fuels and alternative fuel blends, are exempt from the state sales and use tax. However, all fuels are subject to a state fuels user fee of \$0.16 per gallon. Alternative fuels include butane, liquefied petroleum gas, and compressed natural gas. Blended fuels are defined as mixtures composed of gasoline or diesel fuel and another liquid, other than products such as carburetor detergent or oxidation inhibitor, which can be used as a fuel to operate a highway vehicle. (Reference [South Carolina Code of Laws 12-28-110](#), [12-28-310](#), and [12-36-2120](#))

IV Current Policy Concerning the Use of Biodiesel Fuels

Various organizations and agencies having substantial transportation fleets have established policies to comply with applicable laws, directives and regulations. These policies are intended for implementation at the local level to meet operational requirements while complying with higher level mandates regarding the use of biofuels. The policies for the use of biodiesel vary, depending on the end use, as described below.

- **U.S. Navy**

The Naval Operational Logistics Support Center (NOLSC) has issued policies to prevent the offloading of additive fuel (fuel with biocides added) at Navy bulk storage facilities except under very special conditions. Unless other arrangements are made, additive fuel offloaded at Navy bulk storage facilities will be treated as waste oil and a disposal fee imposed [6][8]. (Biodiesel is considered an additive fuel and would therefore not be accepted without a disposal fee.)

The Secretary of the Navy (SECNAV) issued an energy policy message in November 2009. The message sets energy targets for the Navy and Marine Corps as follows: “ Target 1: by 2020 half of our total energy consumption, ashore and afloat, will come from alternative sources; Target 2: by 2020, we will make half of our installations net-zero energy consumers, using solar, wind, ocean and geothermal power generated on base; Target 3: by 2016, the Navy will sail the Great Green Fleet, a carrier strike group composed of nuclear ships, hybrid electric ships running biofuel, and aircraft flying on biofuel; Target 4: by 2015, the Department of the Navy will cut in half the amount of Petroleum we use in our commercial vehicle fleet through phased adoption of hybrid electric, and flex fuel vehicles; Target 5: effective immediately, the Navy and Marine Corps will change the way contracts are awarded. Industry will be held accountable for meeting energy efficiency targets.”

- **U.S. Coast Guard**

The Coast Guard has not issued an overall policy for the use of biodiesel fuels for use on any of its assets. Coast Guard authorized fuels for Cutters and boats are listed in the Naval Engineering Manual [4] along with specific instructions on fuel management, mixing and cold weather use. Biodiesel fuels are not included in the list of approved fuels. The latest revision of the Naval Engineering Manual, Rev F, is currently undergoing review and will specifically exclude the use of any blend biodiesel in Coast Guard Cutters and boats. The Coast Guard is currently seeking an exemption from the Federal mandate requiring the use of renewable fuels, to exclude biodiesel from use on Cutters and boats. The Navy and the Coast Guard currently have a zero allowance of biodiesel in MGO fuels they procure, but realize that it will be difficult, if not impossible, to keep biodiesel out in all cases, they are working to determine the specific minimum content they can live with.

- **GSA**

GSA has issued approval for the use of B20 in GSA Fleet vehicles, provided that the Agency is required to sign a “Terms and Conditions of B20 Use” application. This approval is based on the use of B20 fuel that meets the requirements set forth in ASTM D 6751 and DOD specification A-A-52557 or ASTM D6479-09. GSA also reserves the right to charge the user for any excess fuel usage resulting from the use of B20 and any maintenance charges resulting from the use of B20. Recently GSA has cautioned users about using biodiesel blends over B5 [5].

- **U.S. Military (Non-deployable, Non-tactical)**

Biodiesel (B20) has been approved for use in non-deployable, non-tactical vehicles for the U.S. Army, Navy, Air Force, and Marines. Most military installations using biodiesel obtain it through the Defense Energy Support Center (DESC), which coordinates the federal government’s fuel purchases. DESC is the largest single purchaser of biodiesel in the U.S. MARAD would potentially be impacted by DESC policies and practices for fuel purchases insofar the wartime surge activations of its Ready Reserve Fleet (RRF) are concerned.

The Assistant Secretary of the Navy (Installations and Environment) issued a memorandum on January 18, 2005 stating that all diesel vehicles not specifically exempted shall operate on biodiesel fuel (B20) no later than June 1, 2005 where B20 can be supplied by the DESC, adequate fuel tanks are available, and the use of biodiesel fuel is allowable and practicable considering federal, state and/or local regulatory requirements. Biodiesel or biodiesel blends shall not be used in tactical military equipment or deployable commercial equipment intended to support contingency operations [7]. Recent discussions with DESC indicate that the Air Force and Marines are the main users of B20 at this time, and anecdotal evidence of sustained use exists in many Navy installations such as Port Hueneme and Everett Naval Station.

Naval Fuels and Lubricants Position Paper dated October 27, 2004 recommends that biodiesel or any biodiesel blend use onboard naval and MSC vessels and in USMC-deployed tactical vehicles and equipment should be forbidden [7].

The Tri-Service Petroleum Users Group (Army/Navy/Air Force) Position Statement issued March 2006 supports the current prohibition of the use of biodiesel for tactical applications [9].

The Navy has successfully used biodiesel blends up to B20 for non-tactical marine use such as harbor tugs, launches (*USS Arizona* memorial), floating cranes, etc.

- **United Kingdom Royal Navy**

The Royal Navy has banned the use of biodiesel in ship systems. Therefore, any fuel exchange agreements with the UK could not be honored if operational resources were to permit the use of biodiesel fuels for its vessels refueling at UK ports, or transferring fuel to UK vessels [8].

- **NATO**

NATO does not permit the use of any biodiesel fuel for marine applications. No information was available regarding the use of biodiesel for non-marine applications, but biodiesel blends of up to 5 % are permitted in the EU standard diesel specification [8].

- **Energy Policy Act - U.S. Federal**

Biodiesel is a recognized alternative fuel under the Energy Policy Act of 1992 (EPAAct) as amended in 1996. This act was amended in 1998 by Energy Conservation and Reauthorization Act (ECRA). The amendment allowed qualified vehicle fleets (Government on-road) to use B20 in existing vehicles to generate alternative fuel vehicle purchase credits. This has created significant B20 use by government [1], and prompted ASTM to develop standards to include bio-fuel into new and previously accepted commercial specifications for diesel fuel.

- **Commercial**

The only policy for Commercial Grade Marine fuel is ISO and EN standards. Most suppliers in the U.S. provide marine grade fuel meeting ISO standards, (which do not permit the addition of biodiesel). The ISO standard is currently up for review with recommendations to include up to 5% bio. (This is the fuel used by commercial international carriers.) Local harbor and intra coastal shippers typically purchase marine grade fuel meeting one of the categories under ASTM 975. The marine grade of this fuel is supplied in various grades containing specified properties and additives to meet the user specifications. It also contains, in most cases, stabilizing additives applicable for marine applications. It must be noted that with the recent approval of ASTM 975 (09), the basic specification permits the addition of up to 5% bio which does not need to be reported.

V. Findings

1. Fuel Specifications

Biodiesel is registered as a fuel and fuel additive with the Environmental Protection Agency and meets the clean diesel standards established by the California Air Resources Board (CARB). Neat (100%) biodiesel has been designated as an alternative fuel by the Department of Energy (DOE) and the U.S. Department of Transportation (DOT).

Most of the major producers of Marine fuel manufacture to ISO standards (ISO 8217). This is the fuel normally used by ocean vessels. ISO 8217 does not currently allow the inclusion of bio-fuel, but **there is currently a proposal to permit the addition of “trace” elements of bio (up to 5%) in the basic ISO specification.** This proposal will be voted in early 2010 and could have a major impact on the marine industry. Coastal vessels tend to purchase marine grade fuel using ASTM standards for diesel fuel, and add requirements for sulfur content. Suppliers also add stabilizers and adjust the fuel for temperature conditions, and use ASTM D975 as a base fuel. The basic ASTM D975 specification now permits the addition of up to 5% bio, and B5 is already showing up at marinas across the country.

The marine fuels used in recreational marine operations are primarily off-highway D2 and on-highway D2. The marine fuels used in commercial marine operations are primarily distillates of intermediate and residual oils. The marine fuel industry uses specific names for distillate, intermediate and residual fuels. Marine diesel fuel is not a general term, but refers specifically to an intermediate type fuel. Diesel fuel used for recreational purposes generally has lower sulfur than diesel fuel used for commercial purposes, though in terms of usage it is a small fraction of the diesel fuel used for commercial marine purposes.

In Northern California marinas, No 2 on-highway is used as recreational marine fuel. In other selected marinas in parts of the country, No 2 off-highway is used. Thus, for recreational marine fuel, Northern California has much lower sulfur levels than recreational marine fuel in other parts of the country.

Table 1

DIESEL FUEL TYPES FOR COMMERCIAL MARINE USE

Fuel Type Fuel Grades Common Industry Names

Distillate DMX, DMA, DMB, DMC Gas Oil or Marine Gas Oil

Intermediate IFO 180 380 Marine Diesel Fuel or

Intermediate Fuel Oil (IFO)

Residual RMA-RML Fuel oil or Residual Fuel Oil

Historically, the quality of diesel fuels in the USA was specified by ASTM D975 standard. Since 2004, this standard has covered seven grades of diesel:

| | | |
|------------------|--|-------------|
| No. 1-D S15 | A special-purpose, light middle distillate fuel for use in diesel engine applications with frequent and widely varying speeds and loads or when abnormally low operating temperatures are encountered. Higher volatility than that provided by No. 2-D fuels. | 15 ppm |
| No. 1-D S500 | | 500 ppm |
| No. 1-D S5000 | | 5000 ppm |
| No. 2-D S15 | A general-purpose, middle distillate fuel for use in diesel engines, especially in applications with relatively high loads and uniform speeds, or in diesel engines not requiring fuels having higher volatility or other properties specified in Grade No. 1-D fuels. | 15 ppm |
| No. 2-D S500 | | 500 ppm |
| No. 2-D S5000 | | 5000 ppm |
| No. 4-D | A heavy distillate fuel, or a blend of distillate and residual oil, for low- and medium-speed diesel engines in applications involving predominantly constant speed and load. | |

Heavier fuel oils Grade 5 and 6 (residual), which are used primarily for heating purposes, are described by ASTM D396

The Sxxxx designation was first adopted in the D975-04 edition of the standard to distinguish grades by sulfur content. The S5000 grades correspond to the “regular” sulfur grades, the previous No. 1-D and No. 2-D. S500 grades correspond to the previous “Low Sulfur” grades (D975-03). S15 grades are commonly referred to as “Ultra-Low Sulfur” grades or ULSD.

An ASTM standard (D2069) once existed for marine diesel fuels, but it has been withdrawn. It was technically equivalent to ISO 8217. While some marine diesel engines use No. 2 distillate, D2069 covered four kinds of marine distillate fuels: DMX, DMA, DMB, and DMC and residual fuels. DMX is a special light distillate intended mainly for use in emergency engines.

- DMA (also called marine gas oil, MGO) is a general purpose marine distillate that must be free from traces of residual fuel. DMX and DMA fuels are primarily used in Category 1 marine engines (< 5 liters per cylinder).
- DMB (marine diesel oil, MDO) is allowed to have traces of residual fuel, which can be high in sulfur. This contamination with residual fuel usually occurs in the distribution process, when using the same supply means (e.g., pipelines, supply vessels) that are used for residual fuel. DMB is produced when fuels such as DMA are brought on board the vessel in this manner. DMB is typically used for Category 2 (5-30 liters per cylinder) and Category 3 (≥ 30 liters per cylinder) engines.
- DMC is a grade that may contain residual fuel, and is often a residual fuel blend. It is similar to No. 4-D, and can be used in Category 2 and Category 3 marine diesel engines.
- Residual (non-distillate) fuels are designated by the prefix RM (e.g., RMA, RMB, etc.). These fuels are also identified by their nominal viscosity (e.g., RMA10, RMG35, etc.).

HESS Marine Fuel data sheets show that marine fuel is basically #2 Diesel as per ASTM standard D975 specifications and modified to the user requirements. Local commercial designations for the fuel being used are ordered as D86 or D85 with a limit of 6.6ppm for sulfur.

CHEVRON data sheets show different grades of marine fuel. Some are “commercial grade”, but phone calls and research indicates the Marine Grade (MGO) fuel is supplied in accordance with ISO standards – (which do not permit the addition of bio).

There is currently no field test available to verify the percentage of biodiesel in “Blends” received from distributors. Laboratory testing is required. There is, however a field test to determine if the B100 that is being received meets ASTM D-6751. This is the “pHLip Test” and is endorsed by the National Biodiesel Board (NBB). Phone discussions with the lab technician at the manufacturer indicate that some work has been done to develop a test to determine the percentage of bio in fuel being received, but it remains in the developmental phase. Note: ASTM D-6751 (B100) testing currently requires Gas Chromatograph analysis, which is not practical for on-site verification.

ASTM International is a consensus-based standards group comprised of engine and fuel injection equipment companies, fuel producers and fuel users whose standards are recognized in the United States by most government entities, including states with the responsibility of insuring fuel quality. The specification for biodiesel (B100) is ASTM D 6751-06. This specification is intended to insure the quality of neat biodiesel to be used as a blend stock at 20% and lower

blend levels. Any biodiesel used in the United States for blending should meet ASTM D 6751 standards. ASTM D 6751 allows both animal fat and vegetable oil feed stocks and is not specific to the process employed. Biodiesel is also a legally registered fuel and fuel additive with the U.S. EPA. The EPA registration includes all biodiesel meeting the ASTM International biodiesel specification, ASTM D 6751. The DESC specification for B20 specifically excludes the use of animal fats due to questions of stability and other properties. ASTM has recently approved ASTM D7469-09 for blends B6 to B20. This specification is not currently used or accepted as an approved fuel for marine use but is being accepted for the commercial purchase of B20 by the U.S. government for use in non-tactical applications. The basic ASTM specification for diesel fuel is D 975. This specification is designed for general use and is the base for most other commercial and military specifications. The specification is designed to provide for quality fuel for various climates, temperatures, seasons and operations.

Military specifications are developed to provide quality fuel for various operational environments. The specifications used by the Coast Guard for marine applications are: (NATO) F-76 MIL-DTL-16884L; (NATO) F-44 (JP-5) MIL-DTL-5624U; Navy Purchase description Marine Gas Oil (NPD MGO) Domestic NSN 9140-01-313-7776 and Overseas NSN 9140-01-417-6843; Fuel Naval Distillate (B76) Domestic NSN 9140-01-447-1031; and Diesel Fuel #2 (DF2) domestic NSN 9140-01-456-9443. Specification A-A-59693A, Diesel Fuel, Biodiesel Blend (B20), has been approved for use in GSA lease vehicles and in on-road, non-tactical, non-deployable vehicles for the military when ordered with DESC contract clause C16.27, but not for marine use.

Shown in Table 2, below, is a typical commercial order of marine grade diesel fuel (as supplied by the Washington State Ferry System. This fuel was used as a base for the various biodiesel blends used during the tests described in following sections.

Table 2

**Olympic Pipe Line Company
Product Specifications for Low Sulfur Diesel Fuel #2
Product Code D80 (1)**

| Product Property | ASTM Test Method | Minimum | Maximum | Note |
|---|-------------------------|---------------------|----------------|-------------|
| Gravity, API @ 60° F | D287 / D1298 D4052 | 30 | | |
| Flash Point, ° F. | D93 | 125 | | (2) |
| Viscosity, cst @ 104° F. | D445 | 1.9 | 4.1 | |
| Cloud Point, ° F. | D2500 / D5773 | ASTM | | (4) |
| Pour Point, ° F. | D97 / D5949 | ASTM | | (5) |
| Total Sulfur, wt. % | D2622 / D4294 | | 0.050 | |
| Corrosion, 3 hrs @ 122° F | D130 | | 1 | |
| Carbon Residue, wt. % | D524 | | 0.35 | |
| Ash, wt. % | D482 | | 0.01 | |
| Sediment & Water, % by volume | D1796 / D2709 | | 0.05 | |
| Cetane Index or Aromatic, vol. % | D976 / D4737 D1319 | 40.0 | 35.0 | (6) |
| Distillation, ° F, 50% recovered 90% recovered End Point | D86 | Report 540 | 640 700 | |
| Haze Rating, @ 72° F. | D4176 | | 2 | |
| Color | D1500 | | 2.5 | |
| Workmanship | | Clear and Bright | | (3) |

NOTES:

1. In addition to above specification, products must meet ASTM D975 or latest revision.
2. Test method D93 is the referee method.
3. Product shall be clear and bright and free of suspended matter and water at 72° F or below.
4. Maximum Cloud Pt., +14° F., - November through February.
Maximum Cloud Pt., +24° F., - March through October
Alternate method D5773 may be used, but in case of dispute, D2500 will be absolute.
5. Maximum Pour Pt., +0° F., - November through February
Maximum Pour Pt., +15° F., - March through October
Alternate method D5949 may be used, but in case of dispute, D97 will be absolute.
6. EPA minimum requirement.

2. Availability of Biodiesel Fuels

Biodiesel and biodiesel blends are currently not available for delivery through the normal fuel pipelines. The National Biodiesel Board (NBB), DOE, NREL, and others are currently developing demonstration projects to support the transportation of biodiesel fuels in the existing fuel distribution system. The project is termed “National Biodiesel Infrastructure Development Initiative (2009)”. The main concerns with distribution of biodiesel through the “pipe” are the cleaning effect of bio-fuel on the existing pipe, and contamination of fuels that do not allow for the use of bio products.

The NBB is awaiting funding in order to partner with petroleum products merchant wholesalers to perform pipeline runs with an expected result of understanding how biodiesel behaves in the pipeline, particularly if it is fungible, and why or why not. This project will be the first demonstration of soy-diesel conducted to date on biodiesel movements through private pipelines. This demonstration will raise awareness and dispel speculation about the concerns of moving low-level blends of biodiesel on the commercial pipeline. The project will have an outreach and education component directed at petroleum marketers on the proper procedure to blend, ship, and store ASTM D6751 quality biodiesel. This project will also establish an emergency implementation plan should fuel quality situations occur in the future, as did in Minnesota last winter. Further, it will result in the installation of biodiesel meter-blending terminals at each of two existing petroleum terminals.

In Europe, biodiesel blends of 5% have been transported through pipelines for several years and there are concerns in both Europe and the U.S. on the affects of trace amounts on jet fuels. In the U.S., most of the major pipelines have conducted, or are in the process of conducting, trials of B5 blend shipments through the pipeline. The work, coordinated by the Joint Industry Project (JIP) will determine the long-term affects of regularly transporting B5 blends by pipeline. As of yet, there is no consensus on this subject.

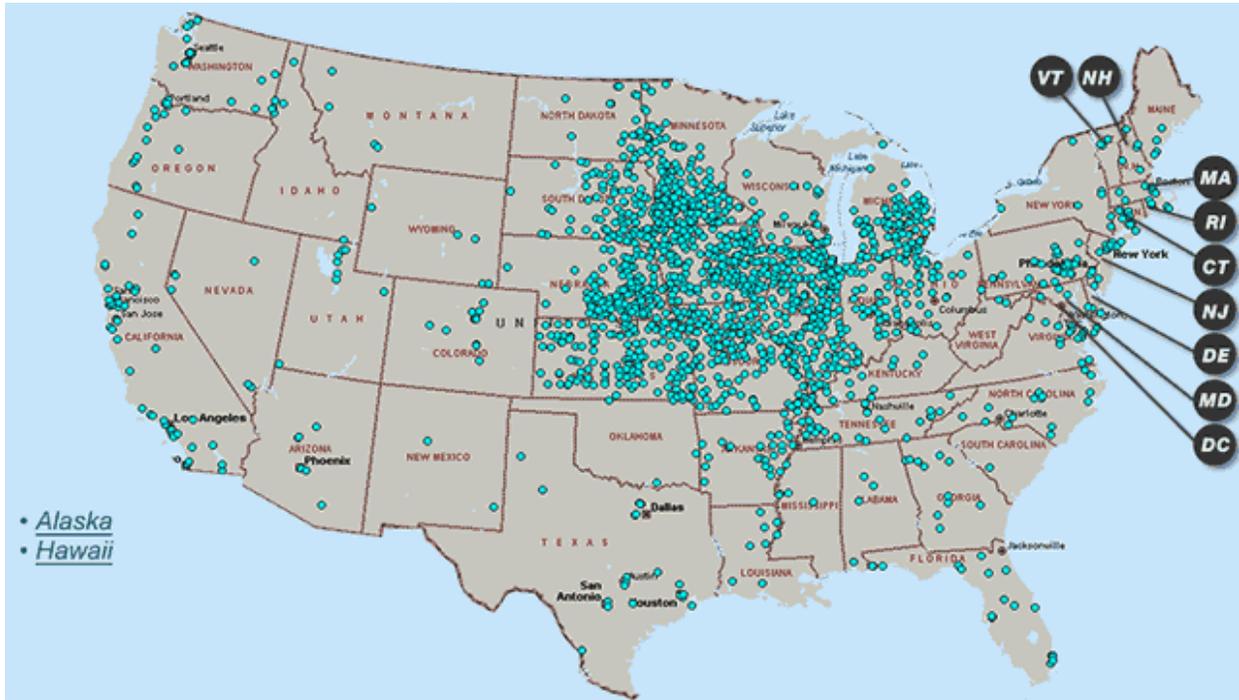
- **Supply**

The National Biodiesel Board has released the following production volume estimates for neat (100 %) biodiesel production in the United States:

FY 2006 – 250 million gallons
FY 2007 – 450 million gallons
FY 2008 – 700 million gallons

The majority of biodiesel produced, distributed and used is in the midwest section of the U.S., as shown in Figure 3, below.

Figure 3. Biodiesel Distributors



Source: National Biodiesel Board

Biodiesel in any blend from B2 to B100 is available from commercial sources in all 50 states. There are currently approximately 1450 distributors nationally. A current listing of registered and National Biodiesel Board distributors for all the states can be found at www.biodiesel.org. Listings of the number of distributors (as provided by the National Biodiesel Board) for sample states with major port facilities are as follows:

| | | | |
|------------|----|----------------|----|
| Texas | 33 | Michigan | 93 |
| NY/NJ | 37 | North Carolina | 20 |
| California | 61 | South Carolina | 2 |
| Washington | 31 | Ohio | 37 |
| Georgia | 14 | Virginia | 22 |
| Wisconsin | 22 | Florida | 38 |
| Oregon | 25 | | |

Biodiesel fuel is available in any blend ratio commercially available in all states. Biodiesel (B20) is available through DESC contract; however it is only available for non-tactical

use. All DESC B20 contracts are for delivery to end-use tanks such as heating boilers or filling stations. DESC has no contracts in place for delivery of B20 to vessels. Discussions with DESC determined that a contract to fuel vessels at a commercial or government pier or berth would involve a negotiated contract for delivery, the problem being that federal and local laws, and regulations, require a special qualification certification for fuel delivery over water. DESC estimates that it would take 3 to 4 months to negotiate a contract for a specific point delivery. Most of the DESC contractors that have the over water qualification only blend and deliver petroleum based fuels to vessels, and have no experience with biofuels. Most distributors that handle biofuels are not familiar with marine deliveries. There are of course exceptions for small blenders and distributors in places like Florida and Virginia, but the combination of being qualified for over water transfer, and being able to provide DESC grade biodiesel is not widespread.

It is further noted that the high flash point requirements for marine fuel means that ASTM D 975 fuel may not have an adequately high flash point to meet military requirements. Mixture with a Marine Gas Oil would therefore be required. However, no DESC bunker contracts for MGO support a biodiesel blend. Even if the challenging technical concerns with using biodiesel in a marine environment can eventually be overcome, this contractual obstacle will also have to be addressed for government contracts.

3. Fuel Performance

Biodiesel fuels (B100) typically contain approximately 10% less energy than petroleum diesel. They however contain no sulfur. The result is lowered emissions, and greater fuel use for the same amount of work performed.

This increased fuel use may not be readily apparent depending on the application. An example is the Washington State Ferry system, where the vessels typically spend a large amount of time in idle or low power mode. During tests conducted with various biodiesel blends, there was no significant change in fuel use from previous periods where petroleum diesel was used.

Emissions are discussed in section VI “**Marine Emissions and Impact of Biodiesel Fuels**”

The main problems experienced with the use of biodiesel fuels have been long-term stability, low temperature performance, and the solvent action of the fuel resulting in clogged filters from dissolved residue. These concerns are the primary reasons for the restrictions for use in military tactical, deployable, vehicles/vessels. There is also concern about power reduction and fuel economy at blends over five percent biodiesel.

- **Fuel Filter Performance**

Biodiesel fuels may result in fuel filter failure due to the solvent properties of the fuel dissolving resins used in some types of cellulosic filters [12]. This property has been reported, but not fully investigated. Qualification procedures for approving fuel filters for use with neat or biodiesel fuel blends do not exist, and should be considered. Based on user reports, it appears

that fuel filters perform satisfactorily when used with biodiesel fuels. Unfortunately, due to the solvent cleaning aspect of biodiesel, the fuel filters become clogged much more frequently. Biodiesel users report that the initial use of biodiesel in grades of B20 and above result in an exponential increase in the use and replacement of fuel filters.

- **Seal Performance**

Biodiesel (B100) is not compatible with some hoses and gaskets. B100 may soften and degrade certain types of rubber compounds found in hoses and gaskets (i.e. Buna N, Nitrile, natural rubber) and may cause them to leak and become degraded. Biodiesel blends of B20 and lower do not significantly degrade elastomers used in diesel engines [11][14].

- **Fuel Consumption**

Fuel consumption is related directly to the energy content of the fuel used and the power generated by that fuel. B100 contains 8% to 11% less energy than No 2 diesel, B20 contains approximately 2% to 3% less energy than No. 2 diesel and B5 contains approximately the same energy as No. 2 diesel. The actual fuel consumption depends on the output requirements placed on the engine. Marine diesel engines are normally designed to operate at higher power and torque levels than on-road vehicles in order to meet mission requirements. Full power is seldom required for on road use (except during acceleration), but routinely called for in afloat tactical operations. Engines operating in the 70% to 80% power range (cruise range for marine operations) will see 1% to 2% increase in fuel consumption and a similar decrease in range when using B20. Increases in fuel use of up to 10% have been reported when using B100 in marine applications [15].

- **Vessel Endurance**

Vessel endurance is directly related to fuel consumption and will vary in the same ratios as discussed above. Vessels using biodiesel will have reduced range, or need to carry additional fuel.

- **Engine Performance – Power**

Biodiesel (B100) contains 11% less energy per gallon than typical No. 2 diesel in the United States. The viscosity range of biodiesel fuel, however, is higher than that of petroleum-based diesel fuel, which tends to reduce barrel/plunger leakage and thereby slightly improves injector efficiency. The net effect of using B100 is a loss of approximately five to seven percent in maximum power output. The actual power loss will vary depending on the percentage of biodiesel blended with the fuel.

B20 will result in power, torque and economy reductions of between 1% and 2% for normal operations. The reduction in top-end power and torque will vary depending on the type, age and condition of the engine, and some tests report a reduction of as much as 3%

power/torque for B20 at “full power” [11][12]. Blends of B5 or less do not cause noticeable differences in performance compared to No. 2 diesel.

- **Cold Weather Use**

A major drawback of biodiesel use is its less favorable cold flow properties compared to conventional diesel. The cold flow properties of biodiesel and conventional petro-diesel are extremely important as both can start to freeze or gel, as the temperature gets colder. If the fuel begins to gel, it can clog filters or eventually it can become thick enough that it cannot even be pumped from the fuel tank to the engine. Cloud point, cold filter plug point and pour point are the normal tests used to satisfy purchase requirements. These requirements must be specified in the purchase requirements and are based on the intended use of the fuel, the time of year it will be used and the geographical location. The supplier/distributor will then custom blend the fuel to meet the use requirements. Blends for cold weather applications usually involve the addition of a lighter grade of diesel like kerosene.

Cold weather properties that are geographic specific are problematic on many oceangoing vessels because of the wide geographic regions over which some of them operate. For example, a vessel may take on fuel in a warm weather port, such as Hawaii, but then transit to a cold weather operating area such as the Gulf of Alaska. Fuel cold weather properties that were perfectly acceptable for local consumption in the warm weather environment may be totally unsuitable when transported with the vessel to its cold weather operating area.

- **Flash Point**

Flash point is a measure of a fuel’s flammability. According to U.S. Code of Federal Regulations, and international agreements (Safety of Life at Sea), marine fuel must have a minimum flash point of 60°C (140°F). There is no recognized specification for a marine grade of biodiesel blend that would meet the minimum flash point requirement. A B20 blend with #2 diesel fuels per ASTM D 975 would have a minimum flash point of only 52°C. The bio component would therefore have to be blended with a marine fuel such as MIL-SPEC F-76, or Navy Purchase Description Marine Gas Oil in order to meet the minimum flash point requirement. The DESC B20 contract has no provision for blending with marine grade fuels, nor do the DESC bunker contracts have provisions for blending in a bio component.

- **Hydrophilic Properties**

Pure biodiesel can hold in solution up to 2.5 times more water than the specification of 0.05 vol. [12][13]. Entrained water affects the cloud point, pour point and cold filter plugging properties of the fuel. Blends of as low as 20% biodiesel can therefore exceed the current limits for absorbed water in all marine grade fuels, and should not be used in any applications where the fuel may be exposed to contact with free water, frequent temperature changes, or high humidity. High water content will also affect the fuel storage stability and may damage engine fuel system components.

- **Emulsification With Water**

When biodiesel fuels are used either pure or in blends, heavy emulsions are formed when in contact with water. Tests have shown that this material will not settle out into its constituent parts over time and cannot be broken or reduced by the usual chemical means [16]. The formation of these intractable emulsion layers would cause operational difficulties for ships that use seawater ballasting fuel tanks, or experience fuel tank water condensation due to operating and environmental conditions. For all practical purposes, it can generally be assumed that any shipboard fuel storage, whether seawater ballasted or not, will have some free water located in the tank bottoms. Water can be brought aboard entrained with the fuel, through condensation of high humidity air brought in via the tank vents, and in high sea state through wave action via the tank vents. All shipboard fuel storage tanks will therefore be susceptible to formation of these emulsion layers. The emulsion layer would plug fuel injection nozzles, filters, and damage engine parts with the ingestion of the seawater in the heavy emulsion layer [16].

There are no established cleaning procedures to effectively remove this emulsification layer from tank surfaces and from interior piping surfaces/piping components. New acquisition vessels are equipped with fuel tank stripping systems to remove water from the bottoms of storage tanks, but older vessels typically do not have this capability. B20 samples have exhibited low levels of water interfacial tension, indicating that water separators, coalescers and centrifugal purifiers in engine fuel systems will not perform as intended [16][17].

Table 3. Selected Properties of Typical No. 2 Diesel and Biodiesel Fuels

| <u>Fuel Property</u> | <u>Diesel</u> | <u>Biodiesel</u> |
|------------------------------|---------------|------------------|
| Fuel Standard | ASTM D975 | ASTM D6751 |
| Lower Heating Value, Btu/gal | ~129,050 | ~118,170 |
| Kinematic Viscosity, @ 40°C | 1.3-4.1 | 4.0-6.0 |
| Specific Gravity kg/l @ 60°F | 0.85 | 0.88 |
| Density, lb/gal @ 15°C | 7.079 | 7.328 |
| Water and Sediment, vol% | 0.05 max | 0.05 max |
| Carbon, wt % | 87 | 77 |
| Hydrogen, wt % | 13 | 12 |
| Oxygen, by dif. Wt % | 0 | 11 |
| Sulfur, wt %* | 0.05 max | 0.0 to 0.0024 |
| Boiling Point, °C | 180 to 340 | 315 to 350 |
| Flash Point, °C | 60 to 80 | 100 to 170 |
| Cloud Point, °C | -15 to 5 | -3 to 12 |
| Pour Point, °C | -35 to -15 | -15 to 10 |
| Cetane Number | 40-55 | 48-65 |
| Lubricity SLBOCLE, grams | 2000-5000 | >7,000 |
| Lubricity HFRR, microns | 300-600 | <300 |

*Sulfur content for on-road fuel will be lowered to 15 ppm maximum in 2006.

- **Microbial Contamination**

Biodiesel fuel is an excellent medium for microbial contamination. In as much as water accelerates microbial growth and is naturally more prevalent in biodiesel fuels than in petroleum-based fuels, care must be taken to remove water from fuel tanks.

Biocides are recommended for conventional and biodiesel fuels wherever biological growth in the fuel has been a problem. Because any additive increases the chances of incompatibility reactions between loads of distillate fuels. Only two biocide products are approved for use on Coast Guard vessels [4] and only with specific approval. On the newest vessels, special fuel tank stripping systems and dedicated seawater ballast tanks are required to limit the collection of free water in the storage tank bottoms thereby controlling microbial growth by limiting the amount of free water in the fuel tanks. If biological contamination is a problem, water contamination needs to be controlled since the aerobic fungus, bacteria, and yeast hydrocarbon utilizing microorganisms (HUMBUGS) usually grow at the fuel-water interface. Biocides that work with diesel fuels should work equally well with biodiesel. Standards or recommended amounts to use, have however not been developed. This may be due to the variations in the chemical makeup and oxygen content of biodiesel fuels. Controlling water contamination is a problem in marine applications as all fuel tanks are vented to the atmosphere and will “breathe” due to sea action, volume changes and temperature changes.

- **Storage Stability**

Storage stability has been identified as a primary area of concern for biodiesel fuel. Most soy-based biodiesel produced in the U.S. cannot meet the European standard for stability.

Stability refers to two issues for fuels: long-term storage stability or aging and stability at elevated temperatures and/or pressures, as the fuel is re-circulated through an engine’s fuel system. Storage stability involves the formation of filter clogging particulates. Filter usage can dramatically increase when attempting to burn unstable fuel. Filter element change out intervals can go from months to hours, and a deployed vessel can quickly exhaust its onboard supply of filter elements. Both diesel engines and gas turbines are susceptible to damage should unstable fuel particles make it past the ship’s filtration system. Fuel injection pumps can stick, injection nozzles coke and clog, and ultimately result in damage requiring overhaul of the engine because of cylinder liner wash down from un-atomized/un-ignited fuel. Gas turbines are particularly susceptible to severe hot section damage from burning unstable fuel. Fuel nozzles that feed the burner cans (these cans are where the combustion takes place and are usually made of titanium) can coke and clog causing a concentrated flame instead of a diffused flame front. This in turn causes a blowtorch effect that can slice through the turbine blades [17]. At this time, there are no ASTM specifications for the stability of biodiesel. The stability test now used is based on oxidation characteristics, and there is debate on whether it can be directly applied to biodiesel fuels. Current ASTM stability work is concentrated on ASTM D 2274. European work is centered on the Rancimat test. Neither has been convincingly linked to the unstable biodiesel characteristics observed in the field.

In biodiesel, fuel aging and oxidation can lead to high acid numbers which may damage aluminum fuel tanks and, high viscosity and the formation of gums, particulates, and sediments that clog filters. Keeping oxygen from the fuel reduces or eliminates fuel oxidation and increases storage life. This is not possible for marine operations, where all vessel tanks are vented to the atmosphere.

In many shore side commercial systems, the fuel turnover is in the range of two to four months. Fuel stability in these conditions has not proved problematic for B100. Tests have however shown that significant changes in fuel properties can and do occur in both B100 and B20 at approximately eight weeks when stored at or above 43°C [18].

Storage stability tests conducted by the Naval Research Laboratory [17] for soy-based blends of B10 and B20 have shown wide variance in results with different samples from different suppliers, even though all samples met current ASTM and military specifications. Several blends failed the storage stability test procedures and would thus lead to filter plugging and other engine operational problems. The blends that failed had similar chemical and physical properties to samples that passed the test, indicating that there is much about biodiesel fuel and blends that is not fully understood. Antioxidant and stability additives had mixed results on the samples tested; indicating that the use of additives with biodiesel fuels is also not fully understood.

As biodiesel degrades with time, in any blend, it forms peroxides and acids. These compounds are generally believed to be precursors to the formation of particulates. These separately, or in combination with other degraded products and entrained compounds, can cause serious damage to fuel tank coatings, fuel tank materials, filters, fuel systems, and engines. The entire process is not well understood, but the end products of degraded biodiesel fuel are well documented [11] [16] [19].

Storage stability has unique shipboard consequences, depending on the vessel's size, mission profile, and fuel system capabilities. Large oceangoing vessels have big fuel storage capacities (over a million gallons) and retain fuel onboard for considerable amounts of time. Large vessels also tend to have greater numbers of fuel tanks and are better equipped to isolate tanks that develop fuel quality problems. They also have somewhat better fuel purification capability to better treat their fuel prior to burning. Smaller vessels on the other hand have greater fuel throughput and turnover. However, they have fewer tanks to allow them to isolate a problem fuel and only basic filtration/water separation capability. These basic shipboard characteristics have to be taken into account when contemplating the use of biodiesel.

Contamination levels in fuel can be reduced by storage in tanks kept free of water, and tankage should have provisions for water draining on a scheduled basis. Water promotes corrosion, and microbiological growth may occur at the fuel-water interface. Underground or isothermal storage is preferred to avoid temperature extremes; above ground storage tanks should be sheltered or painted with reflective paint. High storage temperatures accelerate fuel degradation. Fixed roof tanks should be kept full to limit oxygen supply and tank breathing [11].

All fuel tanks on vessels are vented to the atmosphere and will therefore accumulate moisture and water in an open marine environment and due to wave action. Fuel will be in contact with free water even in tanks that do not use ballast water for stabilization. The effects of biodiesel emulsification with water have been discussed above.

Standard storage and handling procedures used for petroleum diesel can be used for biodiesel. The fuel should be stored in a clean, dry, dark environment. Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene and Teflon. Copper, brass, lead, tin and zinc should be avoided in storage tanks and handling systems. There are currently no handling or storage facilities available for bulk use of blended biodiesel fuels. All are blended at the time they are ordered and then delivered by truck, barge or rail. At least one supplier on the west coast is installing a large capacity (80K barrels) tank to provide biodiesel in a B5 blend. This facility will incorporate “in-line” blending to insure the correct blend, and is being developed to meet State mandates to provide B5 at all fueling facilities.

- **Fuel Additives**

B100 found in the United States cannot be effectively managed with current cold flow additives like some petro-diesel or European rapeseed oil based biodiesel. The U.S. oils and fats contain too high a level of saturated compounds for most additives to be effective. Additives can be used with some success for treating biodiesel blends. Efforts are underway to design new cold flow additives for biodiesel, but manufacturers have limited development resources because biodiesel is currently only a small percentage of the overall business.

Fuel additives used with B5 and B20 blends have not been fully evaluated, but preliminary tests and studies indicate that additives used with current petroleum-based fuels will be effective with biodiesel [18]. The proper amount, or dosing, has not however been determined or standardized. At least one major distributor, World Energy Alternatives LLC, has reported to have developed comprehensive cold weather biodiesel blends including the optimal diesel grade and full range of additive options along with strict storage and handling guidelines to provide biodiesel blend capable of satisfactory operation at sub-zero temperatures. The advertised use has been for generators at ski areas. The company also provides recommendations on additives available for specific fuel requirements [20]. Washington State Ferry testing has indicated that biocides should be used with blended fuel.

The U.S. Navy has issued Technical Advisory 99-12 [6] as clarification to the fuel additive policy. This policy prohibits the off-loading of additized fuel to Navy or DLA storage tanks, barges or ships for inclusion in the fuel inventory. It also prohibits the use of additized fuel for UNREP exercises (where one ship transfers fuel to another). It further states that any tanks accepting improperly additized fuel will require cleaning prior to future use as storage for approved fuels, and the offending unit will be charged the cost of cleaning. Biodiesel is considered to be an additized fuel and would therefore not be accepted at Navy or DLA facilities,

and thereby could affect operations of commercial vessels under Navy or MARAD control in time of crisis.

- **Lubricity**

All U.S. highway diesel fuel is now available with less than 15 ppm sulfur content - ultra low sulfur diesel fuel (ULSD) and all on road vehicles manufactured after 2006 are required to use ULSD. Low sulfur diesel fuel (500 ppm) is available until 2010 when only ULSD will be available. Exceptions to the EPA regulations are Alaska, where LSD may be used, and various states such as California where ULSD is mandated currently for highway, off-road and marine use. This will create lubricity problems in older engines (pre-2006). Producers and suppliers are required to add lubrication additives to correct the problem and to meet current fuel specifications. EPA has mandated the use of ULSD for marine applications, effective 2013. It is not known how this will affect military-use diesel fuels.

Biodiesel blends as low as 2% can improve lubricity of diesel fuels. Producers indicate that other alternatives are less expensive. The alternatives would be added to the petroleum-based fuel to meet ASTM and DLA specifications and could be transported via pipeline. Biodiesel blends and B100, are not currently transmitted via pipeline due to fear of contamination of other products, and are blended at the distributor facility or on site.

The problem of lubricity of ULSD and the interaction with biodiesel blends has yet to be fully addressed by the Defense Logistics Agency or commercial specification societies. Engine manufacturers and fuel system manufacturers are working with suppliers, specification writers and societies to define the impact and correct potential problems and failures.

4. Warranty Issues

There are a variety of statements about biodiesel use from engine and vehicle manufacturers, including some that make reference to warranty. Engine and vehicle manufacturers provide a material and workmanship warranty on their products. Such warranties do not cover damage caused by some external condition. Thus, if an engine that uses biodiesel experiences a failure unrelated to the biodiesel use, it must be covered by the OEM's warranty. Federal law prohibits the voiding of a warranty just because biodiesel was used - it has to be the cause of the failure. If an engine experiences a failure caused by biodiesel use (or any other external condition, such as bad diesel fuel), the damage will not be covered by the OEM's warranty.

Many engine OEMs are acknowledging biodiesel use by stating their observations about harmful effects (or the lack of effects) with various blends in their equipment. Most OEMs declare a lack of harmful effects for B5 and lower blends based on a statement by the leading fuel injection equipment suppliers, as long as the biodiesel meets D 6751 and/or the European biodiesel specification. Some OEMs recognize higher blend levels. More evaluation is underway in the diesel engine industry related to biodiesel and its effects on diesel engines.

Damage directly attributable to biodiesel will not be covered by an engine OEM's warranty, as most engine manufacturers have very specific fuel requirements, but should be covered by the fuel supplier's general liability insurance. New biodiesel users should be sure that their biodiesel suppliers provide liability coverage on their biodiesel or its blends and provide fuel which meets the engine manufacturers' requirements [11]. Generally, bad fuel cases are difficult to prove.

- **The Fuel Injection Equipment (FIE) Manufacturers Position**

FIE manufacturers encourage the development of renewable compression ignition fuels. Experience to date with Rapeseed Methyl Ester (RME) fuels in Europe suggests that with fuels conforming to the existing national FAME (Fatty Acid Methyl Esters) standards at the point of sale in mixtures containing up to 5% volume RME, in petroleum fuel complying with currently accepted quality standards, should not give end-users any serious problems. In the U.S., most biodiesel is produced from soybean oil and is referred to as Soy Methyl Ester (SME).

Certain vehicle models have been adapted by their manufacturers to use blends of 5% and above of good quality RME fuels with petroleum fuel. Other vehicles are adapted to use 100% good quality RME. The FIE manufacturers can supply equipment suitable for these applications.

The original quality of the FAME fuel is defined in draft National Standards which cover all relevant impurities and tramp chemicals from the processing. Suppliers of FAME fuels must be able to demonstrate compliance to these draft standards at the point of delivery to the vehicle or plant. International Standards are based on experience gained with the National Standards being developed to specify the original quality and long-term stability of FAMES. For the FIE manufacturers, a key part of these standards is resistance to oxidation. Aged or poor quality FAME contains organic acids, free water, peroxides and products of polymerization which attack many components thereby drastically reducing the service life of the FIE. Also, as addressed previously, particulate formation is a major concern. Even if these fuels comply with a suitable standard as delivered, the enhanced care and attention required for maintaining the fuels in vehicle or other tanks may entail a high risk of non-compliance to the standard during use.

The FIE manufacturers can accept no legal liability for failure attributable to operating their products with fuels for which the products were not designed, and no warranties or representations are made as to the possible effects of running these products with such fuels.

Non-compliance of the fuel to standards agreed by the FIE manufacturers, whether being evident by appearance of the known degradation products of these fuels, or their known effects within the fuel injection equipment will render the FIE manufacturers' guaranty null and void [12].

Several major engine manufacturers such as Cummins, Detroit Diesel, etc. which supply marine grade engines were queried about warranty issues with regard to the use of biodiesel.

The response was basically the same from all respondents in that they would not warranty engines if failure of the engine or fuel system was the result of fuel which did not meet their specifications. Each manufacturer has published their own fuel specifications, which in most cases mirror ASTM, MIL, NATO and international specifications. Some manufacturers have stated that their warranty only covers biodiesel blends, using approved ASTM blend stock, up to 5% and at least one has stated that blends up to 20% for specific engines should meet their fuel specification requirements. All respondents expressed concerns about the effect of biodiesel on fuel system component such as pumps and injectors. Ultimately, lives are at stake and major accidents due to sudden engine stoppage have to be averted.

Caterpillar

For Caterpillar ACERT Technology engine model numbers C7, C9, C11, C13, C15, C18, C27, C32, and also for Caterpillar 3114, 3116, 3126, 3176, 3196, 3208, 3306, C-9, C-10, C-12, 3406, C-15, C-16, C-18, 3456, 3408, 3412, 3500 Series, C175 Series, 3600 Series, C280 Series, CM20, CM25 and CM32 engines, biodiesel that meets the requirements that are listed in the Caterpillar specification for biodiesel, ASTM D6751, or EN 14214 are acceptable. Biodiesel may be blended in amounts up to a maximum of 30% with an acceptable diesel fuel. This blend is acceptable provided that the biodiesel constituent meets the requirements that are specified by Caterpillar, prior to blending. In addition, the final blend must meet the requirements for distillate diesel fuel approved by Caterpillar. Failures that result from the use of any fuel are not considered Caterpillar factory defects and are therefore not covered by a Caterpillar warranty.

The most commonly available biodiesel blends are B20 which is 20% biodiesel, and B5 which is 5% biodiesel.

For blends of biodiesel above 30%, the Caterpillar dealer for the engine should be contacted for guidance. A complete Caterpillar Scheduled Oil Sampling (S·O·S) Services oil analysis program is required when biodiesel or blends of biodiesel that are above 20% are used. Biodiesel or blends of biodiesel as used in the engine must meet the requirements that are stated in the "Caterpillar Specification for Distillate Diesel Fuel for On-Highway Diesel Engines".

For Caterpillar C0.5 through C4.4 mechanical fuel injection equipped engines that meet both Tier 3 and Stage 3a (Tier3/Stage3a) emissions regulations, biodiesel that meets the requirements that are listed in Caterpillar's biodiesel specifications, ASTM D6751, or EN 14214 may be blended with an acceptable diesel fuel. This blend should be to a maximum ratio of 20% biodiesel to 80% of an acceptable diesel fuel. Use of more than 20% biodiesel can cause premature failures. The repair for these failures would not be covered under the Caterpillar warranty.

For Caterpillar C0.5 through C4.4 mechanical engines that meet Tier2/Stage2 or earlier emissions regulations, for C4.4 and C6.6 Electronic engines, and for 3003 through 3034, 3044, 3046, 3054, 3056, 3064, and 3066 engines, biodiesel that meets the requirements that are listed

in Caterpillar's biodiesel specification, ASTM D6751, or EN 14214 may be blended with an acceptable diesel fuel. This blend should be a maximum ratio of 5% biodiesel to 95% of an acceptable diesel fuel. Use of more than a 5% biodiesel can cause premature failures. The repair for these failures would not be covered under the Caterpillar warranty.

When biodiesel, or any blend of biodiesel is used, the user has the responsibility for obtaining the proper local exemptions, regional exemptions, and/or national exemptions, if required, for the use of biodiesel in any Caterpillar engine that is regulated by emissions standards. Biodiesel that meets the requirements that are listed in Caterpillar's specification for biodiesel, ASTM D6751, or EN 14214 should pose no problems when blended with an acceptable distillate diesel fuel at the maximum stated percentages.

Cummins

Cummins Inc. requires that all biodiesel fuel blends be comprised of biodiesel meeting ASTM D975 and B100 meeting either ASTM D6751 or EN14214. Diesel fuel and biodiesel blends up to B5 must meet the specifications found in their latest technical notice. "Cummins Inc. Required Diesel Fuel Specifications" for biodiesel blends above B5 and up to B20, Cummins Inc. requires that the fuel meet the specifications outlined in ASTM D7467.

Biodiesel fuel can be blended with an acceptable diesel fuel up to 5% volume concentration (B5) for all Cummins engines.

Biodiesel fuel can be blended with and acceptable diesel fuel up to a 20% volume concentration (B20) for the following Cummins engines: ISB CM850, ISB CM2150, ISBe EURO 3, QUB3.3, QSB4.5 Tier 3, QSB6.7 Tier 3, ISC/ISL CM850, ISC/ISL CM2150, ISCe/SLe Euro3, and QSC/QSL Tier 3. ISM CM870, ISX CM875, ISM CM876, QSM11 Tier 3, QSM11 Marine, and QSM11 G-Drive. Additional, information can be found in Cummins Service Bulletin 3379001-18. Cummins has several "disclaimers" regarding the use of biodiesel fuel, and very specific requirements for the Marine use. Advisories state, "...the possibility exists that fuel of this quality (Cummins Specifications) may not be readily available in certain marine markets".

Cummins Inc. test data on the operating effects of biodiesel fuels indicates that typically smoke, power and fuel economy are all reduced.

MAN

MAN Diesel SE produces large, medium and low speed diesel engines especially designed for residual fuel (heavy fuel oil) operation. Regarding biofuel operation MAN Diesel SE has already gained experience for several stationary power plants running on several regenerative fuels like e.g. soy bean oil, animal fat, waste edible fat, palm oil or sun flower oil for several large medium speed 4-stroke marine diesel engine types. All of these fuels have been used as 100% pure raw stock. From this experience, MAN has no objections for operation of these types of fuels for marine applications. A specification of fuel characteristics required for

operation for the engines can be supplied upon request. Main parameters are phosphorus content, iodine number* and total acid number.

Regarding mixtures of regenerative fuels with conventional marine fuels (ISO-8217) like heavy fuel oil (HFO) and marine diesel oil (MDO) have not been tested yet, as this might not be a commercially attractive alternative for engine operators. If this might be relevant in the future, tests have to be carried out regarding mixture stability and side effects like deposits or filter clogging. ISO-8217 does not consider any mixtures with regenerative fuels.

MAN also has experience with operation of large medium speed engines on diesel fuel as it is used in the automotive industry (EN-590). This fuel can contain already mixtures of up to 5% biodiesel.

Fairbanks Morse

On February 1, 2007 Fairbanks Morse Engine announced the approval to utilize up to B100 (100% biodiesel) in its Opposed Piston (OP) Model 38D 8 1/8 diesel and dual fuel engines for continuous operations. A press statement was issued: “Our extensive tests have demonstrated that utilizing B100 fuels that comply with the ASTM D6751 testing and specification had little impact on fuel consumption and power ratings, and had positive impacts on emissions by substantially lowering particulate matter (PM) and CO values”.

Fairbanks Morse’s experience with alternative fuels ranges from Dutch Harbor, Alaska where UniSea, Inc. utilizes up to 100% Fish oil to power six Fairbanks Morse 2.3 MW generator engines to a Dupage County, IL cogeneration facility where digester gas is burned in a Fairbanks Morse 1.5 MW generator engine. In addition, San Francisco State University has been utilizing up to B80 since the late 1990s. Recently, Fairbanks Morse Engine concluded another successful test utilizing Model 38 8 1/8 engines and B100 (soy-diesel) in a continuous application in Story City, IA.

*Note: The Iodine No. is part of the European specs for biodiesel and is not included in U.S. specs. The Iodine No. has to do with the saturation of bio-oils in the finished fuel. MAN requires iodine limit for bio-fuel in any of their engines, not just marine.

Detroit Diesel

Detroit diesel permits the use of B5 biodiesel fuels meeting ASTM D6571 specification, prior to blending. This fuel can be blended up to 5% by volume in petroleum diesel fuel. The finished fuel must meet the requirements shown in the 2007 “Lubricating Oil, Fuel and Filters” bulletin.

Volvo

Volvo permits the use of not more than 5% bio-oil in diesel ready mixed from the oil company. Volvo does not intend carrying out long-term tests on engines for these fuels and was not able to provide any information regarding the testing of biodiesel fuel in marine applications marketed by the Volvo Penta marine group.

Wartsila

Wartsila has delivered some land based engines in Europe that are capable of operating on biofuels. The information provided was sketchy, but indicated that palm oil based fuel was used, and the engines were provided for power generation. They had plans in the early nineteen eighties to construct a plant in Singapore to manufacture “small engines” specifically designed to operate on biofuel. The plan was canceled in 1985 due to the price fluctuations in both petroleum diesel and biofuel oils.

Wartsila worked with Celebrity Cruise Lines/Royal Caribbean Cruise Lines (CCL/RCCL) to develop tests for ship service generators using biodiesel. Work stopped when CCL/RCCL stopped using biofuels due to cost increases. Wartsila has no ongoing projects in the U.S. to develop or test the use of biofuel.

5. U.S. Marine Industry Population and Fuel Use

For the purposes of this study, the fuel use aspect of marine industry operations was investigated. In the U.S., the largest user of marine grade fuel is the U.S. Navy and U.S. Coast Guard. Estimates for fuel use are available that exclude this consumption and include only sales for the fueling of commercial or private boats, such as pleasure craft, fishing boats, tugboats, and oceangoing vessels, including vessels operated by oil companies.

- a. Marine diesel consumption is captured under the “Vessel Bunkering” category in DOE statistics and was pegged at approximately 2.1 billion gallons in 2004.
- b. In a 1998 study citing US Transportation Census Bureau data the “recreational” market (includes for hire “charter” vessels) consumed 136 million gallons of diesel fuel.
- c. Diesel consumption rates in the commercial marine market have remained somewhat steady in the 2 to 2.5 billion gallons per year. Therefore, it is thought

that “recreational” consumption of diesel has remained around 136 million gallons per year.

- d. Estimates of fuel consumption are based on data from the National Association of Charter Boat Operators, charter boat captains and marina managers. A typical charter vessel is a “six-pack” operation, licensed to carry no more than six passengers. These types of vessels would have engines in the 350 hp to 500 hp range [32].

In 1999, the EPA conducted a study of commercial marine activity for deep sea ports in the United States [2][3]. Selected information is included here to indicate the potential market for the use of biodiesel fuels in the U.S. The report included port activities for both domestic and foreign vessels at the top 95 U.S. Deep Sea Ports, and includes all types of commercial vessels (Bulk, Container, Cruise, Dry-Cargo, Excursion, Ferry, Passenger, Reefer, etc.). The total trips at these ports are listed as 989,396 and the total Tonnage handled was shown as 1,821,026,720 tons. While this information is not current, it does match more current studies and indicate the potential market and volume of traffic at U.S. Ports. Some general information from the study is included below as it pertains to this Study.

“The calculation of a commercial marine inventory uses a different approach than that used for other types of non-road equipment. For other types of non-road equipment, EPA’s Non-Road model starts with a national population and allocates it to the local level using various surrogate data related to a given category or type of equipment, such as census, sales, or licensing and registration data. This type of allocation is not possible for the commercial marine model because there is no reliable population inventory of commercial marine vessels. Vessels built and sold in one area are not necessarily used in that area, and many deep-sea vessels are registered with countries other than the U.S. Marine engines operate over great distances, and are thus often far from their home ports. Although various estimates of commercial marine engine populations exist, the contribution of these engines to air quality will vary based on their operational characteristics. For example, a 2,000-hp diesel marine engine will operate one way on a towboat that frequently changes speed and direction over short trips, and operate in a completely different way on a tanker vessel that may travel hundreds of hours at steady power on each trip. For all of these reasons, it is not possible to develop marine activities and emission profiles based on population estimates alone.” [2]

6. Biodiesel Cost Factors

• Cost Factors (General)

Estimating the cost to change from petroleum diesel to biodiesel is relatively easy when discussing on-road use where the fuel is readily available and prices can be compared. The cost to change for marine use fuel however is clouded by the fact that there are no marine refueling or

off-loading facilities that currently provide services for biodiesel fuels, and there are no biodiesel fuels which are designated strictly as marine-use fuels. Any cost analysis must therefore be based on an assumed comparison between on road-use fuel and marine-use fuel, and an estimate of differences in existing infrastructure. Simply put, it is not like changing from regular gas to premium at the local gas station. For marine use, the gas station does not exist for biodiesel fuel, and neither does a standardized fuel specification for marine grade biodiesel fuels.

Major marine insurers (including Lloyds, Ace Ocean Marine, Fisk, Chub Bros. and AIG) were contacted to determine if an insurance premium reduction or credit would be available for the use of biodiesel. All the responses were negative. The insurance industry currently treats a spill as a spill, regardless of the fuel used. Fisk marine insurance has also confirmed that insurance brokers are “starting” to look at credits for the use of biodiesel, but there is no current consensus [39].

The National Biodiesel Board has pursued an initiative since 1995 [34] to obtain changes in the marine pollution regulations, both EPA and Coast Guard, to classify B100 as a “food” even if being used as a fuel. The Department of Agriculture has stated earlier this year, that soy is more valuable as a food source than a fuel. The object of this initiative is to obtain insurance rate reductions for oil spill liability, and is directed at the development of a potential market for biodiesel use by recreational boaters and small near shore commercial operations. There has not been much success in obtaining changes to the regulations to date.

- **Baseline Fuel Costs**

Baseline fuel costs are provided here for both commercial and government purchases of petroleum diesel and biodiesel fuel. The information is included show comparisons between biodiesel costs and the various grades of petroleum based diesel used in marine transportation. FY 2010 prices for Government purchased fuel are:

DESC FY 2010 Standard per Gallon Prices:

| Fuel Grade | \$/Gal |
|-------------------|---------------|
| JP5 | \$2.80 |
| DF2 | \$2.49 |
| F76 (Bunker) | \$2.77 |
| MGO (Bunker) | \$2.87 |

Commercial:

Department of Energy published national average per gallon price as of July 2009 (not equivalent gallons). The prices include the current blender credit of \$1/gal. for B100 used/blended.

Fuel Grade \$/Gal

| | |
|-----------|--------|
| Diesel #2 | \$2.54 |
| B5 | \$2.55 |
| B20 | \$2.69 |
| B100 | \$3.08 |

On a gasoline equivalent basis (energy), the numbers change slightly as follows.

Fuel Grade \$/Gal

| | |
|-----------|--------|
| Diesel #2 | \$2.27 |
| B5 | \$2.29 |
| B20 | \$2.45 |
| B100 | \$3.03 |

Soy oil specific gravity is 925; Fuel oil specific gravity is 890. Using the specific gravity of soy oil and current market “futures” (11/09) prices, ULSD is \$1.9939/gal, and soy oil is \$2.5086/gal. Refining cost to produce B100 drives up the price of B100 (Soy) to approximately \$2.85/gal. Phone calls made to Mansfield Oil and Potter Oil verified prices for B100 (animal fat) as \$2.4080/gal. (Ill) plus delivery charges of 0.08 cents./gal/mile; and \$2.25 for B100 (Soy) delivered to Norfolk. The product is delivered as 99.5% bio, so the Blender can take the current Federal tax credit of \$1.00/gal. for soy-based bio, and \$0.47/gal. for animal fat based bio. This credit was due to expire in Dec. 2009, and neither distributor had any information whether or not the credit would be extended. If not extended, the price of B100 will obviously rise by \$1.00/gal. to \$3.85/gal. for soy-based bio, and \$2.87 for animal fat based bio. In addition, some states currently provide a tax credit of up to \$0.20/gal. for biodiesel used for blending. No information on when/or if this credit may expire is currently available.

- **Tank Cleaning Cost**

Tank cleaning cost is a major cost in conversion to the use of biodiesel fuels in over 5% blends. Blends of 5% or lower should not require special cleaning requirements. Blends of 20% to 100% bio-fuels will however require a thorough cleaning and gas freeing of fuel tanks and fuel lines on marine vessels due to the solvent properties of biodiesel, and the potential impact on fuel oil purifiers and filter replacement cost. The effect of biodiesel fuel on the various corrosion preventive coatings or cathodic protection systems used in marine fuel tank applications has yet to be determined.

Based on information obtained from the Coast Guard Yard in Curtis Bay, MD, a conservative estimate of commercial tank cleaning and gas-freeing of fuel tanks for conversion to B20 or above is:

Remove 5% of fuel remaining in tank @ .16/gal.

Clean to gas free @ .18/gal.

Credit for 98% pure diesel @ .35/gal.

(Assume 50% of removed fuel)

Marine Chemist @ \$550/vessel (min.)

The Washington State Ferries Biodiesel Research and Demonstration Project showed two levels of fuel tank cleaning costs in preparation for testing biodiesel. One level of cleaning involved wiping the tank walls down with B100, the other did not hand clean the tank walls. The costs reported were \$0.45/gal of tank capacity for the B100 wipe, and \$0.31/gal for the lower level of tank cleaning. WSF also reports that the differential cost to use B5 is \$0.04/gal over using MGO.

- **Delivery Cost**

Delivery cost for biodiesel fuel is included in the listed price, for delivery within approximately a 30-mile radius of the Blender. Delivery outside the standard radius is approximately \$3/mile for tanker load transport or \$0.03 to \$0.17/gallon depending on the supplier and the distance.

Two major east coast suppliers of biodiesel, holding current contracts with DESC for delivery of B20, were contacted to determine delivery costs and logistics issues. One was asked to quote for delivery of 1,000 gallons of B99 to a vessel in the Port of Baltimore, the other for a quote for delivery of 5,000 gallons of B99 to a vessel in the Tidewater, VA area. B99 was specified rather than B100 so as to receive a quote that included the credit for the use of soy-based biodiesel. If B100 is delivered, the cost would include an extra charge of \$1.00/gallon, for which the user could be reimbursed under the federal blending credit program. Specifying B99 allows the distributor to claim this credit and do the paper work. The reduced price is then passed along to the user [20] [23].

Both suppliers expressed concerns regarding a delivery site, as their subcontractors are only certified for over-water delivery at a few specific sites.

Delivery charges to a ship in the Houston, TX area would add \$0.17/gal., plus local pumping charges, if within a 50-mile radius of the distributor. The spot price on 01/05/07 for delivery of 20,000 gallons of Soy base B99, to a vessel was about \$2.30/gal. 2009 costs have not changed appreciably relative to base price or delivery charges. Most recently quoted price (as of November 2009) for delivery of soy base B99 biodiesel for delivery to a vessel terminal at Norfolk, VA was \$2.25/gal.

Relocating a vessel to a facility where refueling by truck is permitted would result in additional costs in both lost operational hours and transit costs. No attempt was made to quantify either transit costs or lost operational hours without a detailed analysis of potential delivery points around the country, or the changes that would be required in vessel operations to obtain biodiesel fuel. Such an analysis was beyond the scope of this study.

The delivery of small quantities of biodiesel fuel, as typically required for small vessels, presents another logistics problem. Distributors have expressed a reluctance to provide biodiesel in small quantities (500 gallon or less) even at designated delivery points. Any biodiesel deliveries would require prior contracting arrangements. There are currently no “fuel and go” biodiesel marine facilities. Large storage and distribution facilities are however being planned and constructed for B5 blends to meet State mandates.

- **Maintenance and Filter Cost**

Based on reports from the Washington State Ferry Demonstration Project and follow-up conversations, and information provided from Royal Caribbean, fuel filter change out costs, and associated maintenance costs increase dramatically when changing from petroleum-based fuel to

100%, or blended biodiesel. Reported cost increases occurred even with extensive tank and fuel line cleaning prior to the use of biodiesel. The database for evaluation of filter cost and purifier maintenance relative to large scale conversion to biofuel is not sufficient to make projections on the cost involved with changing fuels. Based on the limited reports from attempts to use biodiesel, it can however be assumed that fuel filter and maintenance costs would increase significantly in commercial marine applications.

- **Iowa State University**

Iowa State University published a paper [35] in early 2009 on the economics of soy-based biodiesel. Excerpts are included here as they are important to understand the interface and concerns of the agriculture community relative to the mandates for renewable fuels. It is also important to note that the study concludes that the price of crude oil would need to rise to approximately \$140 per barrel** and the price of commercial diesel to \$4.50 per gallon before biodiesel would be competitive without a government subsidy.

Relevant and important excerpts from this paper are quoted below with the permission of the University:

- “Although the expanded corn ethanol and cellulosic biofuels mandates contained in the new Energy Independence and Security Act (EISA) have generated the most headlines, the Act’s new biodiesel mandates may have a larger impact on U.S. agriculture over the next few years. Biodiesel use is now mandated to grow from 500 million gallons in 2009 to one billion gallons in 2012. U.S. biodiesel production was expected to decline significantly over the next few years because of low operating margins caused by high feedstock costs. The increased production due to the mandate will put upward pressure on already high vegetable oil prices, which in turn will further increase the cost of producing U.S. biodiesel.”
- “Biodiesel plants will not be built unless investors expect to receive a competitive return on their investment. Before a biodiesel plant can begin to pay out a return on investment, the plant must generate positive operating margins, which are defined as revenue minus all operating costs, including labor, energy, and feedstock costs. In 2007, most U.S. biodiesel plants found that they could not cover their operating expenses. Thus, actual production in 2007 at less than 500 million gallons was far less than the 1.85 billion gallons in capacity.” “Operating costs other than the cost of feedstock currently average approximately 59¢ per gallon. By-products of biodiesel production (glycerin, fatty acids, and filter cakes) provide revenues of perhaps 8¢ per gallon. Most U.S. biodiesel plants operate on soybean oil. It takes approximately 7.6 pounds of soybean oil to produce a gallon of biodiesel. The main source of revenue from biodiesel plants is, of course, biodiesel, which serves primarily as a substitute for diesel fuel.”

* U.S. Petroleum Industry assumes standard Barrel = 42 Gallons

- **Impact of Excess Biodiesel Capacity**

“One implication of the large amount of excess capacity is that soybean oil prices will not be able to fall below the break-even price for any significant amount of time. Prices below break-even levels will trigger increased biodiesel production, which will then result in prices being bid back up to break-even levels. Each billion gallons of excess capacity represents 7.6 billion pounds of soybean oil, or 40% of total U.S. use in 2006. Clearly, increased capacity utilization will have a large impact on soybean oil prices.

The overbuilding of the biodiesel industry thus promises low or zero returns to investors in biodiesel plants. Without the mandate, high feedstock prices will result in little or no production.”

- **Implications of the New Renewable Fuels Standard**

“One of the big winners from passage of the EISA is thought to be the biodiesel industry because of the new mandate for one billion gallons by 2012. But the industry will only be a winner if the mandate leads to future industry profits. Profits will be realized only if the price of feedstock falls below the break-even levels, and that looks unlikely. Biodiesel wholesale prices will need to be greater than \$4.50 per gallon to generate enough revenue to cover such high feedstock prices. There are at least four ways that prices could rise to such a high level. The current method of increasing biodiesel prices is a maximum \$1.00-per-gallon tax credit given to diesel blenders who use biodiesel in their blends.”

“First, if wholesale diesel prices increase to \$4.50 per gallon, then without a tax credit, biodiesel prices would also increase to this level because biodiesel is a good substitute for diesel. But given the historical relationship between crude oil prices and diesel prices, the price of crude would have to increase to \$155 per barrel before diesel prices would increase to \$4.50 per gallon. Futures contracts for crude oil are currently below \$100. Thus, it seems unlikely that market demand for biodiesel as a substitute for diesel will allow biodiesel producers to cover their costs.”

“Second, two sources of market demand for biodiesel are the exports market and as a lubricity component in ultra-low-sulfur diesel blends. Just as the willingness to pay for ethanol as an octane enhancer and as an oxygenate is greater than the price of gasoline, the willingness to pay for biodiesel as a lubricity agent may be greater than the price of diesel. Tax breaks for biodiesel provided in other countries may have the same effect. There is some evidence that diesel blenders and exporters are willing to pay more for biodiesel than for diesel. In the first week of January 2009, the Iowa spot price of biodiesel was \$4.15 per gallon. Subtracting the \$1.00-per-gallon tax credit results in a market demand price of \$3.15 per gallon. The spot price of Midwest diesel was approximately \$2.80 per gallon, indicating a 35¢-per-gallon difference in the market demand price for biodiesel and diesel. However, to generate a market demand price of \$4.50 per gallon for biodiesel with this level of market price premium would require crude oil prices of \$140 per barrel. Exported quantities would not be counted toward the renewable fuels standard.”

“Third, the price of biodiesel could be increased to \$4.50 per gallon if the purchase of biodiesel by blenders were subsidized. The subsidy would have to vary inversely with the price of diesel to ensure a \$4.50 biodiesel price. If blenders are willing to pay 35¢ more per gallon for biodiesel than for diesel, then the required variable tax credit would equal \$4.15 minus the wholesale price of diesel. The cost of meeting the biodiesel mandate using tax credits would be borne fully by taxpayers [35].” “If the government simply mandated that diesel blenders use levels of biodiesel required by the EISA, blenders would have to pay biodiesel producers a price high enough to allow the producers to stay in business to produce the required volumes. Blenders would then have to sell the blender product at whatever price they could induce diesel consumers to pay. The cost of the biodiesel mandate would be shared by consumers. [Therefore] fourth, and lastly, biodiesel prices could be increased enough to cover feedstock costs and blenders.”

7. Summary of Biodiesel User Reports/Case Studies

There is considerable interest in the U.S. to develop workable programs for the use of biodiesel products. This interest is centered on several factors:

- Comply with the U.S. Energy Policy Acts of 1992, and 2005
- Comply with various State emission laws, both current and pending
- Comply with current and forthcoming EPA limits on emissions
- Economic benefits of current Federal and State tax and credit incentives

Numerous producers, suppliers and users were contacted to determine actual results and problems/benefits from the use of biodiesel fuels. The implementation and use of biodiesel products, from B1 to B100, has met with mixed success. Some notable examples are discussed below. Probably the most significant tests and studies of biofuel for marine applications have been conducted by The Washington State Ferry System (WSF) and Celebrity Cruise Lines/Royal Caribbean Cruise Lines (CCL/RCCL). These tests were conducted during actual marine use on both gas turbine and diesel propulsion systems, over extended periods, and include both operational and emissions testing. We thank both WSF and CCL/RCCL for providing this information and allowing us to include the information in this report.

- **GSA**

GSA has approved the use of B20 in leased fleet vehicles provided that the customer agency assumes any additional operational costs. Prior to using B20, the customer agency is required to sign a “Terms and Conditions of B20 Use” application. GSA is not responsible for any problems resulting in engine failure or warranty issues resulting from fuel that does not meet the manufacturer specifications or requirements. The use of B20 in GSA fleet vehicles has not resulted in significant problems. The GSA-approved fuel specification is the same as that used by DESC. GSA has recently issued a notice to users regarding biodiesel fuels and additives, cautioning that the use of biodiesel blends greater than B5 may void manufacturer’s warranties.

The notice further encourages owners/operators to familiarize themselves with and be cognizant of the recommendations provided by each manufacturer [5]. The GSA specification for B20 has not been officially recognized as a national standard by the Engine Manufacturers Association.

- **U.S. Military**

The U.S. Army, Navy, Air Force, Coast Guard and Marine Corps all use B20 meeting either the DESC or ASTM specifications, and purchased under commercial contracts throughout the country, for their non-tactical, non-deployable vehicles in order to meet federal alternative fuel requirements and to reduce the consumption of petroleum fuel. No major maintenance issues have been reported, and feedback has been positive for non-tactical use of the fuel.

The U.S. Coast Guard uses ASTM975 for commercial purchase of MGO at various points. They have received batches in Puerto Rico and Minnesota, from both DESC and commercial distributors which did not meet standard fuel specifications, with mixed results. In one case, they got up to 20% bio and it clogged the fuel filters. In other cases, they got B2 to B5 which also clogged the fuel filters.

- **Washington State Department of Transportation (DOT) – Washington State Ferry System (WSF)**

The Washington State Ferry System (WSF) has been a leader and a pioneer in the research of biofuels for application in the marine industry. They have been conducting studies and large scale testing of biofuels since 2003. The tests and demonstrations have been conducted in actual marine applications on operational ferries, with diesel engine prime movers, and during various weather conditions. The tests conducted were unique in that there are very few examples of biofuel testing that have been conducted for commercial marine applications. The tests are also significant in that the Ferry System uses approximately 17 million gallons/year, and over 1.8 million gallons of blended fuel were consumed during the various tests over a six (6) year period.

The initial testing was done under a “**Clean Fuel Study**” conducted between May and September 2003. The project was to quantify and compare vessel emissions while burning high sulfur diesel (HSD) fuel with vessel emissions generated while burning lower sulfur diesel fuels (LSD, ULSD) and a bio-blend of 20% biodiesel/80% LSD (B20). Stack tests were conducted for a single vessel using the various fuels and during various operations.

The results of the tests were that the use of bio did not significantly change the emissions. The main contribution to increased emissions was the sulfur content of the fuel being used. The results for all emissions (NO_x, CO, Particulate, SO_x) were nearly the same for LSD and the LSD/Bio-blend (B20). The use of ULSD resulted in lower emissions than any of the other fuels. The sulfur content of the various fuels is: HSD—3000 ppm, LSD---300 ppm, ULSD---15 ppm. The full report of this test is included in Appendix 1.

The second initiative was the **Biodiesel Research and Demonstration Project**. This project consisted of three (3) Phases and was initiated in 2004 with assistance from state, local

and private entities. The Project was specifically directed to address the use and handling of biodiesel fuels in a marine environment, and the impact of reducing emissions of particulate matter, which had been determined to be the leading airborne health risk in Puget Sound. The final report was released on May 8, 2009 and is included as Appendix 1 of this Report, along with applicable appendixes to the Project report. Unfortunately, extensive emission testing was not conducted due to budget constraints. The Project did, however, provide important data regarding the use, handling and operability of biodiesel in a marine environment. The Project concluded that biodiesel blended fuels can be used in marine applications but cautioned that problems such as filter clogging may arise unless preventive measures are taken.

Engines in the tests were: EMD A-645-FB, Cummins NTA 855, Detroit series 60 DDEC and GE 7FDM 12EFI. WSF used 1,395,604 gal. of blended fuel and 201,600 gal. were B100. A biocide meeting MIL S-53021A was also used, and recommended for future tests.

The WSF system conducted biodiesel fuel testing in 2004-5 over a period of several months using a B20 biodiesel blend (20% soy biodiesel and 80% low sulfur diesel) in three vessels. This pilot program experienced challenges due to excessive clogging problems in the ferries' centrifugal fuel purifiers and plugging of fuel filters during the tests.

While these operational issues were challenging, the test was successful in that the ferry system learned important information that would assist in their 2008 Biodiesel Research and Demonstration Project. The pilot program was conducted on a 130-car ferry using B20 biodiesel. The test was conducted over the course of several months and the use of approximately 80,000 gallons of fuel. The test was not successful in that fuel filters clogged so badly that they were unable to be fully cleaned. Prior to the use of B20, filters were changed every 6 months. With B20, filters had to be changed as often as four times a day. A review of the information provided indicates that tanks were properly cleaned prior to the test, not ballasted with sea water, and fuel was ordered, delivered, tested and met, current ASTM and DESC specifications for biodiesel.

The Environmental Protection Agency projected that using a B20 fuel was expected to reduce diesel particulate by approximately 10%, carbon monoxide by 11% and hydrocarbon emissions by 21%. The U.S. Department of Energy (DOE) awarded a grant to Puget Sound Clean Air Agency (PSCAA) to perform a scientific study to determine appropriate fuel specifications, fuel handling procedures, and conduct fuel trials using biodiesel blended fuels in WSF operations.

Washington State University (WSU) was selected to lead the research project team conducting the two-year project. The team members included the University of Idaho (UI), Imperium Renewables, Inc. (IRI), and The Glosten Associates. After extensive project development, the actual demonstration project began March 9, 2008.

The goals of the project were (1) to test current fuel specifications for biodiesel and biodiesel blended fuels, (2) to develop biodiesel product handling guidelines for use in a marine environment and (3) to demonstrate that biodiesel blended fuels can be successfully used in marine applications in the Pacific Northwest. The fuel test work plan was designed to test the use of biodiesel on three WSF vessels during normal vessel operations. The vessels and routes selected were the same vessels and routes used in the 2004 pilot test. All three vessels used B5-B20, which was the highest biodiesel blend used (B20) in the ferry tests.

Biodiesel from different feedstock sources were tested in each vessel, including canola-based biodiesel, soy-based biodiesel, and biodiesel with a high cloud point. All biodiesel used met the current version of the ASTM D6751 specification. The fuel blends tested were incrementally raised from 5% to 20%, with samples being taken at critical junctures to ensure fuel quality.

Excess sludge buildup formed in the fuel purifier of one of the vessels after one month of operation, which was similar to the problem experienced in the 2004 pilot test. The research team performed extensive research to find causes of the problem. The sludge samples studied contained metal (~11% ash), water (11-17%), and major fractions of organic materials including 8-octadecenoic acid methyl ester from canola biodiesel, and bacteria. WSU researchers found active bacteria were present in the sludge samples from the purifier, and the bacteria played a key role in the sludge formation. Microbial growth in the ferry system was one of the major causes for excessive sludge formation that resulted in filter clogging. Discussions with WSF operators indicated that sludge formation from microbial growth has been encountered with conventional diesel fuel also. The excessive sludge problem was solved by the application of biocide in the fuel during the studied period. Biocide application is strongly recommended when biodiesel blend fuels are used in marine applications.

This project demonstrated the viability of using B20 biodiesel in year round marine conditions. The results obtained from this project are expected to be directly transferable to other marine applications, as well as being beneficial to land-based end-users. The key lessons learned from these test are as follows:

- a) ASTM biodiesel fuel standards provided adequate safeguards to ensure high product quality.
- b) Fuel quality was not affected by biodiesel feedstock (i.e. soy, canola, and high cloud point fuel).
- c) The percentage of biodiesel (B5 – B20) used in the fuel did not impact vessel operations.
- d) Use of biocides is recommended in all future testing with biodiesel. Although comparisons of sludge formation between conventional diesel fuel and biodiesel were primarily anecdotal, vessel operations using biodiesel may require increased maintenance of fuel filtration systems.
- e) The high humidity of marine environments appears to promote microbial growth.

Symptoms similar to those on the WSF vessels experienced in 2004 have been reported by others, including white milky fluid in fuel bowls, black deposits between filter pleats and general increase in filter servicing and change-out. None of these symptoms were reported to have occurred at the extreme levels reported by WSF in the 2004 test, and centrifugal fuel purifiers were not mentioned in other applications. However, marine fuel systems are somewhat different from other applications in that most others do not centrifuge their fuel.

The literature review conducted during the study suggests that several factors, including water content, temperature, and oxidation, could affect biodiesel quality. The findings relative to this project are summarized below.

- a) Analysis suggests that biodiesel oxidation may not be a key factor in clogging, due to the limited availability of free oxygen, short dwell time, and low temperature.
- b) Cold flow properties, as reflected by relatively high cloud and pour points, may limit biodiesel blended fuel applications under low temperature conditions because particles might be formed in fuel.
- c) Biodiesel has a strong tendency to absorb moisture due to its chemical properties. Because of this tendency, the use of biodiesel in a high humidity marine environment is challenging. Minor compounds, such as sterol glucosides, could form precipitate which agglomerate over time into flocs and sediment, probably leading to clogged filters. The sterol glucoside content can vary from supplier to supplier based on both the biodiesel origin and the form of processing technology.
- d) Actual operational tests have shown that tank cleaning before transitions from long term petroleum diesel fuel use to biodiesel is necessary for effective problem-free biodiesel operation.

WSF Interview 11/17/09:

Preliminary research on the marine use of biodiesel fuels had established that the Washington State Ferry System was among the very few entities with operational experience. As a matter of fact, this organization has been a pioneer in this regard. So it was deemed that an on-site visit to the Washington State Ferries be conducted and to conduct an on-site interview. A few questions had remained after reviewing the WSF documentation on the “Demonstration Project”. An on-site interview was requested and granted. Key discussion items discussed are summarized below:

- **Fuel Testing:** The Washington State Ferries Biodiesel Research and Demonstration Project Final Report addressed several issues with fuel testing. Please provide information as to the testing specifications used to test for Bio% and microbes. (ASTM 7371) And where they were tested (UI) **WSF:** The University of Idaho performed the

analysis on all fuel purifier sludge. I am not aware of what specifications that were used specific to microbial growth. I can get a contact at U of I.

- **Fuel Specifications:** Chevron lists all their marine fuel as meeting ISO specifications. At this time, I don't believe that the ISO specification permits "bio". How does the Washington State "Renewable Fuels Standard" impact the mandatory use of bio in marine diesel? Do you bypass the ISO standard by simply ordering LSD or ULSD? **WSF:** The State has a mandatory renewable fuel standard RFS but it has not been adequately enforced. There is a legislative movement to perhaps change this in the next legislative session. WSF's fuel specification specifies ULSD per D975 ASTM specification.
- **The latest ASTM specification** for diesel (ASTM975) now permits the addition of up to 5% bio, with NO reporting required. Does this impact your operations? **WSF:** Yes, we are currently loading a B5 blend on six of our vessels. The fuel supplied meets D975 and WSF has no specification criteria for biodiesel component.
- **Fuel tank cleaning:** Section 5.2 of the final report indicates that cleaning resulted in the "possible" emulsification of bio fuel. Any additional information? **WSF:** The cleaning of the tanks did not cause any emulsification. It was thought in the 2004-05 tests that any residual water left in the tank (if there was any) could have been the cause of the purifier sludge formation.
- **Fuel tank cleaning:** As described in the final report, was quite extensive. Do you have any cost information on this that can be related to surface area or volume? **WSF:** WSF did two levels of fuel tank cleaning. The higher level of cleaning that resulted in wiping the tank walls down with B100 cost around \$20k per vessel. That is for four tanks with a total volume of 45k gallons. The lower level of cleaning did not wipe tank walls with B100 and costs were around \$14k for similarly sized vessels. (\$0.45/gal for high level, \$0.31/gal for lower level)
- **Fuel Filters:** Do you have any comparative information on the use, or cost of fuel filters when using straight diesel vs. bio fuel? **WSF:** Depending on the feedstock, we experienced different levels of filter usage. With 10% Petroleum diesel, typical primary filtration usage is monthly change outs. With the use of B21 Soy blend change-outs can be as frequent as twice daily.
- **Fuel Blending:** Page 20 of the final report describes using "splash blending" and later mentions the use of stainless steel totes to store B100 for metered blending. Clarification requested. **WSF:** The delivery truck was loaded with the correct volume of biodiesel by volume (5-10-20%) through a meter. The truck then went to the fuel loading rack and bottom loaded (at 300 GPM) the petroleum diesel. This is what is meant by "splash blending" (The metering was just for volume for each compartment in the delivery truck, prior to loading the petroleum diesel. They used approx. 18M gal of blended fuel during the test period. The Harbor Island fuel facility that has an in-line blending facility to produce B5 was not in operation during the WSF's most recent testing period.)
- **Fueling Facility:** I would like to see where and how fuel was blended at your fueling facility, if possible. This will not be possible as the Shell Terminal is a secure facility

and I don't have access to this. WSF uses approx. 18M gal of fuel/yr. Fuel is received from 3 facilities. The Harbor Island (Shell) facility provides B5 using a sophisticated in-line blending procedure and an 80K barrel heated and insulated holding tank – complete with a humidity control and dryer system. The delivery lines are also heated. Fuel is provided to tank trucks which are driven to, and on the ferries, and loaded directly to the vessel fuel tanks. There is NO over the water fueling facility in the Seattle area for delivery of bio-blends. The other two fueling facilities in the area are in the process of developing systems for the bulk handling of biodiesel blends.

- **Bug Alert test strips:** What are these? **WSF:** Not sure of the reference. WSF tests for water in the fuel tanks using water test strips or water detecting paste.
- **Fuel cost:** Do you have any information on the differential in fuel cost, **and use**, between straight diesel and B20? **WSF:** During our testing, a B20 blend had a differential price of about 45 cents per gallon. We are currently running a B5 blend of Soy on six vessels and the differential cost is approximately 4 cents per gallon. (They did measure actual fuel use, and did NOT notice a significant consumption difference during the test. This may have been due to the operating characteristics and the fact that various blends were used.)
- **Conclusions and Recommendations of the WSF Report:** #16 of this section (Final Report) recommends additional tests. Do you have any plans to conduct them? **WSF:** WSF is seeking funding for the cost differential between petroleum diesel and a B20 biodiesel blend. WSF would also like to conduct tests at higher blend percentages and to conduct a test of B20 for a longer duration say 5 years. At this time, WSF does not have funding plans for such tests.
- **Emissions:** The “Executive Summary” states that EPA expected reduced emissions from the use of bio diesel. Were any tests conducted to verify this expectation? **WSF:** No emission testing was done as funding was not available. (WSF previously conducted emission testing using HS, LS, ULS, B5, B10 and B20 blends on a single vessel.)

Post Interview Follow-Up

- Discussed the effects of biodiesel blends on tank coatings and cathodic systems. WSF does not use coating systems on fuel tanks. Info on these subjects was forwarded to WSF after this interview, along with engine manufacturer warrantee information and plastic “tote tank” information.
- WSF New Vessels (under construction) will meet the latest “Tier” standards in accordance with MARPOL Annex 6 for “Emissions Standards” .
- Field Test for Bio: WSF mentioned the “pHliptest” as a means to field test for bio quality. A review of this on www.phliptest.com indicates that this test is only for B100, but is a cheap and accurate test to verify the quality of B100 being used as an additive for blended fuel. Contact with the manufacturer and developer of the test confirm that it is intended for use in testing B100 fuel.
- A review of previous discussions with WSF indicated that loading of biodiesel required a lot of “down time” for the vessels, due to cold flow characteristics; and that when using

B20, exhaust temperatures are 20 to 30 degrees lower than when using straight diesel. This causes problems with the engine turbochargers.

- **Cruise Line Industry (Royal Caribbean/Celebrity Cruises)**

During the period 2005-2008, Celebrity Cruise Lines consumed 240,890 Metric Tons of biodiesel fuel at three locations - Key West, Florida; Vancouver, Canada; and Grays Harbor, Washington. The fuel was a B97-B99 blend and mostly used Palm oil as the preferred biodiesel fuel. The vessel engines were GE-LM2500 Gas Turbines which had been “tuned” by GE to accept high grade bio-fuel. After some initial filter clogging problems, engine operation was satisfactory. To provide fuel for the Alaska route, the following steps were taken:

2006 - Rented a storage tank in Vancouver and had the product delivered (railcar, ship, and truck) and stored. A local barge company was hired to bunker the fuel to the vessels accordingly.

2007 - Rented a storage tank in Grays Harbor, Washington. Chartered Stolt tankers to bring the product from Malaysia to WA where it was stored and blended. Chartered a small tanker for the season to pick up the product in Washington State and bring it to Vancouver to bunker the vessels.

Celebrity currently is not using biofuel due to the increased cost of the feedstock, resulting in biodiesel being a more expensive option than MGO, and the fact that it results in approximately 10% more fuel use for the same route. Low sulfur Marine Gas Oil currently meets EPA regulations for emissions, and relative to “Cold Iron” and in-port generator use, the company is using exhaust traps and other means to reduce emissions to meet the standards and regulations.

The cruise line industry is actively testing and using biodiesel fuels to meet environmental emission standards, mitigate spill litigation, and take advantage of “blender credit” for the use of biodiesel. The cruise line industry was the world’s largest user of biodiesel fuel for marine application but recently reverted to the use of LSD or UULSD due to economic factors mentioned above. The main use to date has been with B100 in gas turbine-powered ships but tests are planned for diesel applications. Several ships have operated with B100 which meets the current ASTM standard. The preferred base for this fuel is palm oil due to the improved cold flow characteristics, but supply is short and demand is high. Strict fuel management is in place, and dedicated barges, pipelines temperature requirements, and testing is enforced at single point loading facilities. Turnover time at fueling facilities is short due to known use. Fuel tanks are typically centerline mounted, and not exposed to ambient seawater temperatures, and not compensated with or exposed to contact with seawater. Fuel use is approximately +10% percent due to the lower BTU value of B100.

In 2006, Royal Caribbean Cruise lines conducted an “Emission Survey” on GTS INFINITY. The test was conducted to determine the effects of using B100 fuel with the GE

LM2500 main propulsion plant. The results were compared to previous tests on GTS CONSTELLATION, as follows:

A similar turbine powered vessel: GTS Constellation was monitored for NO_x emissions in 2005 while firing Marine Gas Oil (MGO). The results of measurements on two turbine exhausts, each operated at about 75% load, was 5.8 and 5.3 g/kWh of NO_x. The NO_x emissions from the GTS Infinity, while firing B100 biodiesel at 75%, load was 4.8 g/kWh. This data, while limited in scope suggests the firing of biodiesel fuel results in less NO_x than firing with MGO at equal operating load in a marine gas turbine.

The data is interesting in that the NO_x emissions were 10% to 14% lower than when using MGO and all emissions were lower than MARPOL Annex VI for diesel engines. Previous information reported on the use of biodiesel fuel in diesel engines indicated that the NO_x levels would increase. The combustion process in a gas turbine is evidently sufficiently different than a high compression diesel to produce these results.

- **NOAA**

National Oceanic and Atmospheric Administration (NOAA) embarked on a “Green Ship Initiative” in 1999. It was led by the Great Lakes Environmental Research Laboratory (GLERL). This was a five-year project to convert vessels to bio products and involves three (3) research vessels as test platforms, the largest of which is a 67-foot Army T-boat. The project was a success in that a 41-foot patrol boat has been converted to a B100 use vessel, though non-catastrophic problems were noted with filters, seals and hoses. Biofuels are not normally used from December through March due to cold flow problems. Fuel use is predictable and delivery is from tank trucks [26][27].

- **Arlington County, Virginia**

Arlington County, Virginia, implemented the use of B20 fuel in 2001 on a total fleet of 227 vehicles of which 138 are buses. B20 is not used in any equipment where long term storage is an issue. They have a central storage facility of one 24,000-gallon underground tank and one 30,000 gallon underground tank. Turnover rate for the fuel is approximately 30 days and weekly deliveries are received. The addition of <10 micron filters has been provided on all dispensing units. The reporting period is through June 2004. There were no noticeable changes in repair or maintenance frequencies. Driver comments however report a change in power levels, which return to normal when refueling with commercial grade diesel. Special additives and blending are required between October 1 and March 15 to improve cold flow characteristics. The fuel order specification meets the ASTM standard for B100 using virgin soy oil as a base [28].

- **Marine Corps Air Station (MCAS), Yuma**

In February 2006, problems started showing up in biodiesel fuel issued from the fuel farm for general service equipment. Pumps, vehicles and equipment, including generators and starting units showed systemic problems related to deteriorated fuel. The biodiesel was added to the fuel farm tanks and evidently proper stability additives were not. Much of the equipment sustained permanent damage. Reference [29] is a graphic presentation of the results of improper blending of biodiesel with petroleum based fuels and/or lack of strict fuel husbandry practices.

- **UK and European Union (EU)**

The EU Fuels Directive (2003/17/EC) currently limits the concentration of biofuel content of conventional petrol and diesel to 5% by volume. This is reflected in the British standard for diesel, BS EN 590, which permits a biofuel content of up to 5% by volume without affecting the vehicle manufacturer's warranty. Oil companies and vehicle manufacturers, working with biofuel producers have agreed a standard-BS EN 14214-for vegetable oils suitable for blending with conventional diesel to ensure that the product meets the technical requirements of modern diesel engines. The main base feed stock used is rapeseed oil.

There were approximately 106 sites selling biodiesel blend in the UK at the end of 2004. The amount sold represents less than 0.1% of the UK's sales of conventional diesel. Biodiesel is available in Austria, France, Italy, Germany, Sweden and the UK.

It was recently announced that Maersk will be collaborating with Lloyd's Register's Strategic Research Group and a consortium of Dutch contractors to conduct a two-year feasibility study on the sustained use of biodiesel in marine engines. The feasibility study will take place on board the Maersk Line containership, *Maersk Kalmar*. The tests will start with lower blends of biodiesel (B5–B7), gradually moving up to higher blends.

- **U.S. Army, Fort Leonard Wood**

The Fort Leonard Wood Directorate of Logistics-Transportation Division has made great strides in the use of Biodiesel (B20) fuel. Since opening fueling stations in March 2003, the base issued more than 600,000 gallons of B20 in the following three years for their 700 vehicle diesel burning vehicle fleet. After initial fuel filter problems, there had been no significant B20 related maintenance issues during the three-year demonstration. The fuel was ordered in accordance with DESC specifications and delivered mixed and stored in 12,000-gallon tanks with an approximate three-week turnover. No fuel was stored for longer than six months, and was tested every quarter [30].

Subsequent to the initial demonstration, filter and injector problems resurfaced with the use of B20. Clogged fuel injectors and the need for frequent dispenser pump filters changes in cold weather, prompted the base to renegotiate the fuel contract to provide a mixture of B5 rather

than B20. During fiscal year 2009, the base dispensed a total of 158,252 gallons of B5; down from a high of 229,272 gallons in fiscal year 2007.

8. New Technology Initiatives

Opportunities for innovation exist in the development of newer generations of feedstock which have the combined attributes of being fast growing, not requiring fertile land and not leaving a significant carbon footprint. **Algae** has taken a foothold as a next generation source of biofuel source since it has all the above-mentioned attributes. The energy from algae holds potential as an economically viable, low emissions fuel because they consume CO₂ and reduce greenhouse gases. The development of technology to grow and refine algae to usable fuel is however a complicated process that involves genomics, synthetic biology, microbiology, biochemistry and various refining techniques. The advantages of biofuels from photosynthetic algae are numerous:

- Algae can be grown using land and water unsuitable for plant or food production, unlike some other first and second generation biofuel feedstocks.
- Select species of algae produce bio-oils through the natural process of photosynthesis – requiring only sunlight, water and carbon dioxide.
- Growing algae consumes carbon dioxide, reducing greenhouse gases.
- Algae have the potential to yield greater volumes of biofuel per acre of production than other biofuel sources. Algae could yield more than 2,000 gallons of fuel per acre per year of production. Approximate yields for other fuel source are far lower:
 - Palm---650 gallons per acre per year
 - Sugar cane---450 gallons per acre per year
 - Corn---250 gallons per acre per year
 - Soy---50 gallons per acre per year
- Algae used to produce biofuels are highly productive. As a result, large quantities of algae can be grown quickly, and the process of testing different strains of algae for their fuel-making potential can proceed more rapidly than for other crops with longer life cycles.
- If successful, bio-fuels from photosynthetic algae could be used to manufacture a full range of fuels including gasoline, diesel fuel and jet fuel that meet the same specifications as today's products.

The potential to use algae as to produce biofuels has not gone unnoticed by the major oil producers. Most have invested large sums to develop, test and produce biofuels from photosynthetic algae.

- Exxon Mobil expects to spend more than \$600 million in a partnership with Synthetic Geonomics, Inc. to develop, test and produce biofuels that are compatible with existing transportation technology and infrastructure.
- Royal Dutch Shell has partnered with HR Biopetroleum in a joint venture called Cellana, to construct a demonstration facility on the Kona coast of Hawaii Island to grow marine

algae in open air ponds to extract vegetable oil for testing as biofuel. The program will include scientists from several major universities, and will use algae strains indigenous to Hawaii or approved by the Hawaii Department of Agriculture.

- Chevron has entered into a collaborative research and development agreement with the U.S. Department of Energy's National Renewable Energy Laboratory to identify and develop algae strains that can be economically harvested and processed into finished transportation fuels such as jet fuel. The initiative is being funded by a division of Chevron, and involves bio-reforming. This is a process by which bio-oils derived from the decomposition of biological feedstocks are then converted into hydrogen and biofuels.
- BP and Martek Biosciences Corporation announced on 11 August 2009, a multi-year Joint Development Agreement to work on the production of microbial oils for biofuels applications. The goal is to establish proof of concept for large-scale, cost effective microbial biodiesel production through fermentation. BP has agreed to contribute up to \$10 million to the initial phase of the collaboration.

A further challenge and opportunity for technological innovation exists in the area of bio-processing (i.e. finding commercially viable methods and processes to convert the newer feedstocks to biofuel in large batches). Biofuels produced from photosynthetic algae can be processed into fuels similar in structure to today's gasoline and diesel fuels. This would help to ensure the fuels are compatible with existing transportation technology and infrastructure. The development processing technology is not currently mature enough to produce transportation fuel economically.

Another area that can benefit from technology initiatives is infrastructure development for biodiesel storage and distribution. Government funding has been earmarked for pushing new technologies in these areas, with the larger goal of eliminating dependence on foreign oil and the shorter term goal of creating jobs.

Of the nearly \$564 million in Recovery Act funding announced in December 2009, up to \$483 million will go to 14 pilot-scale and 4 demonstration-scale bio-refinery projects across the country. The remaining \$81 million will focus on accelerating the construction of a bio-refinery project previously awarded funding. Collectively, these projects will be matched with more than \$700 million in private and non-Federal cost-share funds, for total project investments of almost \$1.3 billion.

The Bio-Refinery Assistance Program, authorized through the earlier 2008 Farm Bill, promotes the development of new and emerging technologies for the production of fuels that are produced from non-corn kernel starch biomass sources. The program provides loan guarantees to develop, construct and retrofit viable commercial-scale bio-refineries producing advanced biofuels. The maximum loan guarantee is \$250 million per project.

On February 3, 2010, President Obama announced a series of steps to boost biofuel production in the United States. The newly-established Biofuels Interagency Working Group also released a report spelling out ways to promote the development of the biofuels industry in

the United States in connection with the long-term renewable fuels standard of 36 billion gallons per year by 2022. The strategies include supporting the development of first and second generation biofuels with the additional focus on accelerating third generation biofuels development and supporting feedstock research and demonstration.

The DOE and USDA are the agencies leading these initiatives. In order to meet these goals, several grant programs have been established and many grants have already been awarded. Significant grants awarded to date are:

- \$59M to make ethanol directly from carbon dioxide and seawater using algae to produce 100,000 gallons of fuel grade ethanol per year.
- \$28M to produce a diesel substitute through the fermentation of sweet sorghum and co-produce lubricants, polymers and other petro-chemical substitutes.
- \$36M to produce renewable diesel and jet fuel from woody biomass.
- \$3M to complete preliminary engineering design for a future facility producing jet fuel, renewable diesel substitutes and high-value chemicals from plant oils and poultry fat.
- \$3M to complete preliminary engineering design to produce green gasoline and diesel from woody biomass, agricultural residues, and algae.
- \$34M to convert wood to green gasoline by fully integrating and optimizing a multi-step gasification process to process 21 metric tons of feedstock per day.
- \$30.5M to convert switch grass and woody biomass into ethanol using a biochemical conversion process.
- \$25M to produce high quality green diesel from agriculture and forest residues using advanced pyrolysis and steam reforming.
- \$25M to validate the projected economics of a commercial scale bio-refinery producing multiple advanced biofuels producing algae oil that can be converted to oil-based fuels.
- \$31M to produce green gasoline, diesel, and jet fuel from agricultural residue, woody biomass, dedicated energy crops, and algae.
- \$135M to cultivate algae in ponds that will ultimately be converted into green fuels, such as jet fuel and diesel.

VI. Marine Emissions and Impact of Biodiesel Fuels

The consensus of the international scientific community on carbon emissions, as reported in the *Wall Street Journal* in December 2009, is that the marine transportation industry contributes between 3% - 5% of the total world's carbon emissions. The recent climate change summit in Copenhagen, Denmark, highlighted the need to reduce emissions to control global warming. Proposed changes in engine design exhaust remediation, sulfur content of fuel, and the potential use of biodiesel fuels, offer possible solutions to meet the global goals.

Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the Clean Air Act. The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter compared to emissions from high sulfur diesel fuel. Comparisons with emissions generated from gas turbine engines and the use of ultra low sulfur petroleum diesel fuels are not, however, well documented.

The California Air Resources Board (CARB) has estimated [36] in a report delivered in April 2008, that of 2400 premature deaths due to emissions from the movement of goods in California in 2005, approximately 370 (~15%) were due to ships within 24 miles and harbor craft within 24 miles of port. They have an aggressive approach to reduce state wide risk 85% by 2020, and have implemented standards for lower sulfur fuel (1,000 ppm) in 2010 for auxiliary engines. Additionally, the mandatory use of shore power at dock, and ship incinerator ban will be phased, to reduce emissions by 80% by 2020. New fuel regulations are proposed to require the use of low sulfur fuel (1,000 ppm) for main engines and boilers by January 2012. (Low and ultra low sulfur diesel is already being used extensively for harbor craft in both California and Washington State.)

Emission test results from Royal Caribbean and Washington State Ferry System tests were discussed previously in the "User Reports" Section. The results show that while biodiesel does reduce emissions, nearly the same results can be achieved by switching to ULSD.

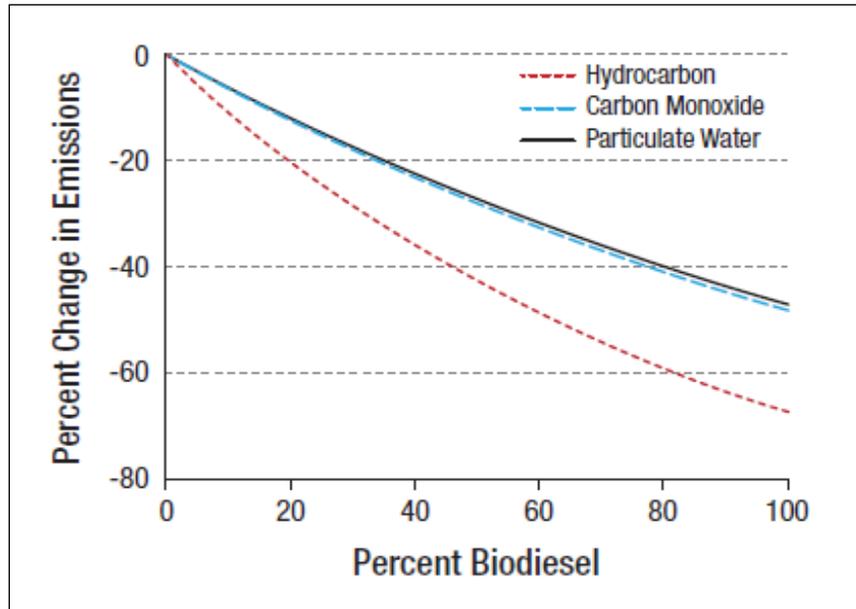
The National Renewable Energy Lab has reported that biodiesel reduces exhaust (PM), hydrocarbon (HC), and carbon monoxide (CO) emissions from most modern four-stroke CI or diesel engines. The benefits occur because biodiesel contains 11% oxygen by weight. The fuel oxygen allows the fuel to burn more completely, so fewer unburned fuel emissions result. This same phenomenon reduces air toxics, which are associated with the unburned or partially burned HC and PM emissions. Testing has shown that PM, HC, and CO reductions are independent of the biodiesel feedstock. The EPA reviewed 80 biodiesel emission tests on CI engines and has concluded that the benefits are real and predictable over a wide range of biodiesel blends. EPA's review also indicated that B20 increased NO_x by about 2% relative to petroleum diesel use. A more detailed analysis of the database examined by EPA, plus more recently published results, confirms the positive impact of B20 on emissions of HC, CO, and PM. However, examination of the NO_x results shows that the effect of biodiesel can vary with engine design, calibration, and test cycle. At this time, the data are insufficient for users to conclude anything about the average

effect of B20 on NO_x, other than that it is likely very close to zero. In contrast, when biodiesel is used in boilers or home heating oil applications, NO_x tends to decrease because the combustion process is different (open flame for boilers, enclosed cylinder with high-pressure spray combustion for engines). The NO_x reduction seen with biodiesel blends used in boilers appears to be independent of the type of biodiesel used. In blends with heating oil up to 20% biodiesel, NO_x is reduced linearly with increasing biodiesel content. For every 1% biodiesel added NO_x decreases by 1%. A B20 heating oil fuel will reduce NO_x by about 20%. Sulfur dioxide (SO₂) emissions were also reduced when the two fuels were blended, because biodiesel contains much less sulfur than typical heating oil does. A 20% blend of biodiesel in heating oil will reduce SO₂ by about 20%. Heating oil and diesel fuel dyed red for off-road use (agriculture, power, boiler fuels, construction, forestry, and mining) can contain as much as 500 ppm sulfur. Blending biodiesel into off-road diesel fuel can significantly reduce SO₂ emissions. Non-road diesel will transition to 15 ppm sulfur beginning in 2010.

Emission test results used and reported by DOE are usually not relevant to marine applications as most tests were completed on much smaller engines and the sulfur content of the base fuel used for comparison was usually not reported. ISO and MARPOL standards for Tier 2 and 3 engines will also change the picture on emissions. These engines will reduce the NO_x and other emissions through improved engine combustion design, fuel delivery systems and external emission controls. Emissions (in general) are related to the age and type of engine or boilers used, NO_x remediation installed, and exhaust filters and traps.

Biodiesel (B100) contains 0% sulfur, and therefore SO_x emissions are reduced, but B100 is seldom used in large commercial marine applications and must be blended with marine grade diesel. Most marine users are simply shifting to Low sulfur or Ultra-low sulfur diesel fuel to meet emissions standards; plus the cost of bio-diesel vs. marine grade diesel and associated handling and maintenance cost, makes the current use of biodiesel not economical. The chart below (Figure 4) shows the NREL published effects of biodiesel use on emissions. It does not, however, reflect the baseline diesel fuel used to develop the chart.

Figure 4. Biodiesel Impact on Emissions



EPA has taken an aggressive stand on emissions and the use of lower sulfur fuels to meet emissions goals. These goals are described in the following statement issued by EPA:

“June 1, 2007: Refiners will begin producing low-sulfur diesel fuel for use in locomotives, ships, and non-road equipment (those used in industries such as agriculture and construction). Low-sulfur diesel fuel must meet a 500 parts per million (ppm) sulfur maximum. This is the first step of EPA’s Non-road Diesel Rule, with the eventual goal of reducing the sulfur level of fuel for these engines to meet an ultra-low standard (15 ppm) to enable new advanced emission-control technologies for engines used in locomotives, ships, and other non-road equipment.

EPA has adopted a comprehensive national program to reduce emissions from future non-road diesel engines by integrating engine and fuel controls as a system to gain the greatest emission reductions. To meet these emission standards, engine manufacturers will produce new engines with advanced emission-control technologies similar to those already expected for highway trucks and buses. Exhaust emissions from these engines will decrease by more than 90%. Because the emission-control devices can be damaged by sulfur, we are also adopting a limit to decrease the allowable level of sulfur in non-road diesel fuel by more than 99%.

These reductions in NOx and PM emissions from non-road diesel engines will provide enormous public health benefits. EPA estimates that by 2030, controlling these emissions would annually prevent 12,000 premature deaths, 8,900 hospitalizations, and one million work days lost.”

Marine Diesel Engines (EPA statement)

On December 22, 2009, the EPA issued final rules for more stringent emission standards for marine compression-ignition engines. The statement and a summary of the rules are as follows:

“Diesel engines on ocean-going vessels such as containerships, tankers, bulk carriers, and cruise ships are significant contributors to air pollution in many of our nation’s cities and ports. Their emissions are expected to increase even more in the future, as our trade with other countries increases, and ship emissions will represent a larger share of our national emission inventories.”

The statement provides general and technical information on EPA’s coordinated strategy to address emissions from oceangoing vessels. This strategy includes EPA’s regulations for the largest marine diesel engines as well as the U.S. Government’s international efforts to reduce air pollution from oceangoing vessels through the designation of an ECA and new international standards for marine diesel engines. When taken together, the elements of the coordinated strategy are expected to result in significant improvements in U.S. air quality and public health.

There are two types of diesel engines used on oceangoing vessels: main propulsion and auxiliary engines. The main propulsion engines on most oceangoing vessels are very large "Category 3" marine diesel engines (those with per-cylinder displacement at or above 30 liters). Auxiliary engines on oceangoing vessels typically range in size from small portable generators to locomotive-size engines with power of 4,000 kilowatts or more. Auxiliary engines on U.S.-flagged oceangoing vessels are subject to EPA’s marine diesel engine standards for engines with per-cylinder displacement up to 30 liters per cylinder.

- **EPA Regulations**

On December 22, 2009, EPA announced final emission standards under the Clean Air Act for new marine diesel engines with per-cylinder displacement at or above 30 liters (called Category 3 marine diesel engines) installed on U.S.-flagged vessels. The final engine standards are equivalent to those adopted in the amendments to Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL). The emission standards apply in two stages: near-term standards for newly-built engines will apply beginning in 2011, and long-term standards requiring an 80% reduction in nitrogen dioxides (NO_x) will begin in 2016.

EPA is adopting changes to the diesel fuel program to allow for the production and sale of diesel fuel with up to 1,000 ppm sulfur for use in Category 3 marine vessels. The regulations generally forbid production and sale of fuels with more than 1,000 ppm sulfur for use in most U.S. waters, unless operators achieve equivalent emission reductions in other ways.

EPA is also adopting provisions to apply some emission and fuel standards to foreign-flagged and in-use vessels that are covered by MARPOL Annex VI.

- **Emission Control Area Designation (EPA -Proposed)**

On July 17, 2009, the joint proposal from the United States and Canada to amend MARPOL Annex VI to designate specific areas of our coastal waters as an Emission Control Area (ECA) was accepted in principle at the International Maritime Organization (IMO). In addition, France has joined the ECA proposal on behalf of its island territories of Saint-Pierre and Miquelon, which form an archipelago off the coast of Newfoundland. The proposal was circulated among member states for six months. Recently, member states who are parties to MARPOL Annex VI voted to adopt an amendment designating the North American ECA. Designation of this ECA will deliver substantial public health benefits to many people living in the U.S., Canada and French territories, as well as to marine and terrestrial ecosystems.

In practice, implementation of the ECA would mean that ships entering designated areas will need to use compliant fuel for the duration of their voyage that is within that area, including time in port as well as voyages whose routes pass through the area without calling on a port. The quality of fuel that complies with the ECA regulation will change over time. The North American ECA could go into force as early as 2012. From the effective date until 2015, fuel used by all vessels operating in designated areas cannot exceed 1.0% sulfur (10,000 ppm). Beginning in 2015, fuel used by all vessels operating in these areas cannot exceed 0.1 % sulfur (1,000 ppm). Beginning in 2016, NOx after-treatment requirements will become applicable.

The Emission Control Areas were requested, in part, from information presented in an April 2009 EPA Study [37] which showed coastal emissions from marine vessels as follows:

Table 4

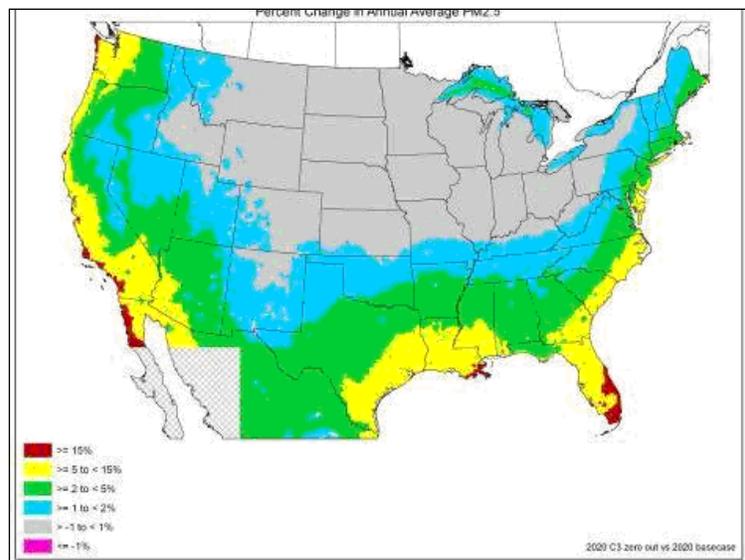
2002 Regional and National Emissions from Category 3 Vessel Main and Auxiliary Engines

| Region | Metric Tonnes | | | | | | |
|----------------------------|-----------------|------------------|---------------------|---------------|---------------|-----------------|-------------------|
| | NO _x | PM ₁₀ | PM _{2.5 a} | HC | CO | SO ₂ | CO ₂ |
| Alaska East (AE) | 18,051 | 1,425 | 1,311 | 597 | 1,410 | 10,618 | 657,647 |
| Alaska West (AW) | 60,019 | 4,689 | 4,313 | 1,989 | 4,685 | 34,786 | 2,143,720 |
| East Coast (EC) | 219,560 | 17,501 | 16,101 | 7,277 | 17,231 | 145,024 | 8,131,553 |
| Gulf Coast (GC) | 172,897 | 14,043 | 12,920 | 5,757 | 14,169 | 104,852 | 6,342,139 |
| Hawaii East (HE) | 22,600 | 1,775 | 1,633 | 749 | 1,765 | 13,182 | 818,571 |
| Hawaii West (HW) | 31,799 | 2,498 | 2,297 | 1,053 | 2,484 | 18,546 | 1,151,725 |
| North Pacific (NP) | 26,037 | 2,154 | 1,982 | 938 | 2,090 | 15,295 | 990,342 |
| South Pacific (SP) | 104,155 | 8,094 | 7,447 | 3,464 | 8,437 | 60,443 | 3,796,572 |
| Great Lakes (GL) | 15,019 | 1,179 | 1,085 | 498 | 1,174 | 8,766 | 541,336 |
| <i>Total Metric Tonnes</i> | <i>670,135</i> | <i>53,358</i> | <i>49,089</i> | <i>22,324</i> | <i>53,444</i> | <i>411,511</i> | <i>24,573,605</i> |



Figure 5. EPA Proposed Emission Control Areas [37]

These areas were determined from the results in the April 2009 EPA report which determined the contribution of emission pollution from ships have a significant impact on PM concentrations, not only in coastal areas, but also far inland. Projections were made to the impact of vessel emissions to year 2020. The percentage contribution of ships to annual average PM concentrations was projected to be greater than 15% in parts of southern FL, southern LA, and the northern and southern Pacific coastline. The impact of ship emissions on PM concentrations also extends well beyond the U.S. coastlines. As can be seen in Figure 6, below, the projected contribution of ships to annual average PM concentrations in many inland areas, such as Tennessee, Nevada, New York and Pennsylvania, is up to 2%.



**Figure 6
Percentage Contribution of Ships to Annual Average PM Concentrations in 2009 [38]**

- **International Standards**

The International Maritime Organization (IMO) facilitates development of standards to control air exhaust emissions from the engines that power ships. The IMO is the United Nations agency concerned with maritime safety and security and the prevention of marine pollution from ships. The international air pollution standards are found in Annex VI to the International Convention on the Prevention of Pollution from Ships (MARPOL). Committees of the IMO meet periodically to consider and adopt revisions to the various annexes of MARPOL. The following paragraphs describe both the currently applicable international air pollution standards as well as amendments that have been recently adopted but have not yet become enforceable.

- **IMO MARPOL Annex VI Amendments**

In October 2008, member states of the IMO adopted new international standards for marine diesel engines and their fuels (2008 Amendments to MARPOL Annex VI) that will apply globally, once the amended treaty is ratified by enough parties. The amendments establish additional, more stringent emission requirements for ships that operate in designated coastal areas where air quality problems are acute. These new global and geographic standards have the potential to significantly reduce air pollution from ships, and provide important benefits to our national air quality.

Under the new global standards, NO_x emissions will be reduced, and the fuel sulfur cap will drop to 5,000 ppm in 2020 (pending a fuel availability review in 2018). Under the new geographic standards, ships operating in designated areas will be required to use engines that meet the most advanced technology-forcing standards for NO_x emissions, and to use fuel with sulfur content at or below 1,000 ppm. To obtain the full benefits of the program, the United States has proposed designation of an Emission Control Area off our coasts.

EPA is addressing emissions from marine engines in two ways, through their fuels requirements, and through their emission limits.

In May 2004, as part of the Clean Air Non-road Diesel Rule, EPA finalized new requirements for non-road diesel fuel that will decrease the allowable levels of sulfur in fuel used in marine vessels by 99%. These fuel improvements, which begin to take effect in 2007, will create immediate and significant environmental and public health benefits by reducing PM from new and existing engines.

In March 2008, EPA finalized a three part program that will dramatically reduce emissions from marine diesel engines below 30 liters per cylinder displacement. These include marine propulsion engines used on vessels from recreational and small fishing boats to towboats, tugboats and Great Lake freighters, and marine auxiliary engines ranging from small generator sets to large generator sets on oceangoing vessels. The rule will cut PM emission from these engines by as much as 90% and NO_x emissions by as much as 80% when fully implemented.

The final rule includes the first-ever national emission standards for existing marine diesel engines, applying to engines larger than 600kW when they are remanufactured -- to take effect as soon as certified systems are available, in 2008. The rule also sets Tier 3 emissions standards for newly-built engines that were to phase in beginning in 2009. Finally, the rule establishes Tier 4 standards for newly-built commercial marine diesel engines above 600kW, based on the application of high-efficiency catalytic after treatment technology phasing in, beginning in 2014.

MARPOL Standards (Emissions)

International Maritime Organization (IMO) is an agency of the United Nations which has been formed to promote maritime safety. It was formally established by an international conference in Geneva in 1948, and became active in 1958 when the IMO Convention entered into force (the original name was the Inter-Governmental Maritime Consultative Organization, or IMCO, but the name was changed in 1982 to IMO). IMO currently groups 167 Member States and 3 Associate Members.

IMO ship pollution rules are contained in the “International Convention on the Prevention of Pollution from Ships”, known as MARPOL 73/78. On September 27, 1997, the MARPOL Convention has been amended by the “1997 Protocol”, which includes Annex VI titled “Regulations for the Prevention of Air Pollution from Ships”. MARPOL Annex VI sets limits on NO_x and SO_x emissions from ship exhausts, and prohibits deliberate emissions of ozone depleting substances.

The IMO emission standards are commonly referred to as Tier I, Tier II and Tier III standards. The Tier I standards were defined in the 1997 version of Annex VI, while the Tier II/III standards were introduced by Annex VI amendments adopted in 2008, as follows:

- 1997 Protocol (Tier I)—The “1997 Protocol” to MARPOL, which includes Annex VI, becomes effective 12 months after being accepted by 15 States with not less than 50% of world merchant shipping tonnage. On May 18, 2004, Samoa deposited its ratification as the 15th State (joining Bahamas, Bangladesh, Barbados, Denmark, Germany, Greece, Liberia, Marshal Islands, Norway, Panama, Singapore, Spain, Sweden, and Vanuatu). At that date, Annex VI was ratified by States with 54.57% of world merchant shipping tonnage.

Accordingly, Annex VI entered into force on May 19, 2005. It applies retroactively to new engines greater than 130kW *installed on vessels constructed on or after January 1, 2000*, or which undergo a major conversion after that date. The regulation also applies to fixed and floating rigs and to drilling platforms (except for emissions associated directly with exploration and/or handling of sea-bed minerals). In anticipation of the Annex VI ratification, most marine engine manufacturers have been building engines compliant with the above standards since 2000.

- 2008 Amendments (Tier II/III)—Annex VI amendments adopted in October 2008 introduced (1) new fuel quality requirements beginning from July 2010, (2) Tier II and III NO_x emission standards for new engines, and (3) Tier I NO_x requirements for existing pre-2000 engines.

The revised Annex VI enters into force on 1 July 2010. By October 2008, Annex VI was ratified by 53 countries (including the United States), representing 81.88% of tonnage.

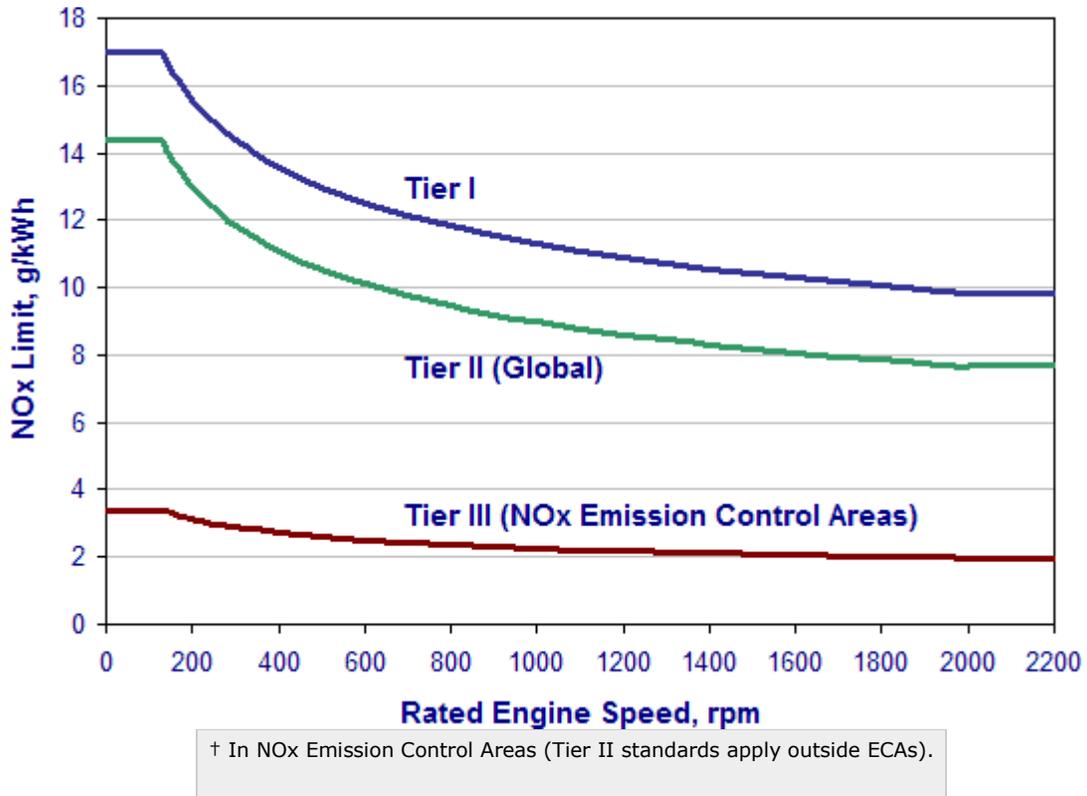
Emission Control Areas. Two sets of emission and fuel quality requirements are defined by Annex VI: (1) global requirements, and (2) more stringent requirements applicable to ships in Emission Control Areas (ECA). An Emission Control Area can be designated for SO_x and PM, or NO_x, or all three types of emissions from ships, subject to a proposal from a Party to Annex VI.

Existing SO_x Emission Control Areas include the Baltic Sea (adopted: 1997 / entered into force: 2005) and the North Sea (2005/2006). Future Emission Control Areas could also include zones around pollution sensitive ports and are being aggressively investigated and implemented in specific U.S. ports, like L.A. and San Francisco.

NO_x emission limits are set for diesel engines depending on the engine maximum operating speed (n, rpm), as presented graphically in Figure 1. Tier I and Tier II limits are global, while the Tier III standards apply only in NO_x Emission Control Areas.

Figure 7. MARPOL Standards for NOx

| MARPOL Annex VI NOx Emission Limits | | | | |
|-------------------------------------|-------|------------------|----------------------|----------|
| Tier | Date | NOx Limit, g/kWh | | |
| | | n < 130 | 130 ≤ n < 2000 | n ≥ 2000 |
| Tier I | 2000 | 17.0 | $45 \cdot n^{-0.2}$ | 9.8 |
| Tier II | 2011 | 14.4 | $44 \cdot n^{-0.23}$ | 7.7 |
| Tier III | 2016† | 3.4 | $9 \cdot n^{-0.2}$ | 1.96 |



MARPOL Annex VI NOx Emission Limits

Tier II standards are expected to be met by combustion process optimization. The parameters examined by engine manufacturers include fuel injection timing, pressure, and rate (rate shaping), fuel nozzle flow area; exhaust valve timing, and cylinder compression volume.

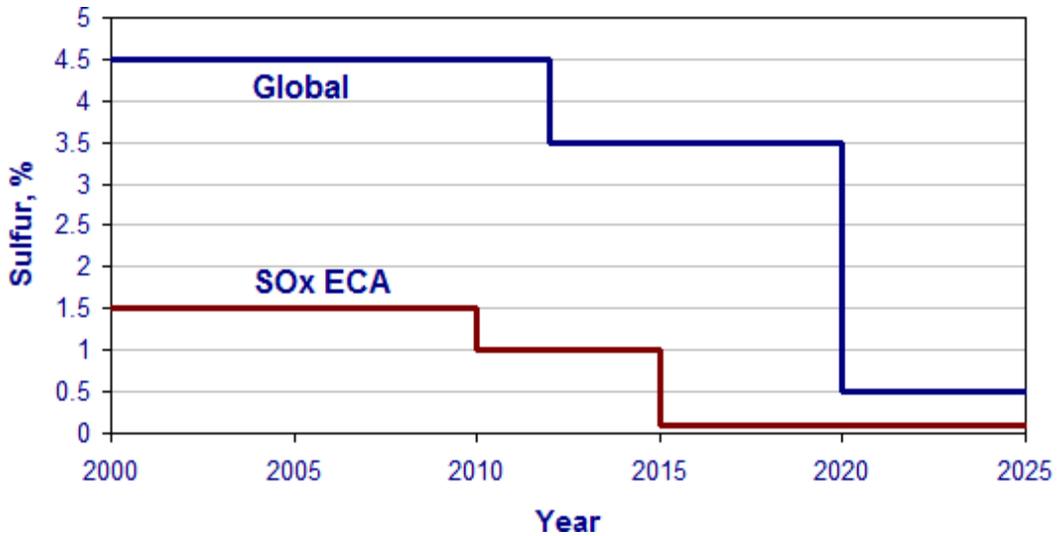
Tier III standards are expected to require dedicated NOx emission control technologies such as various forms of water induction into the combustion process (with fuel, scavenging air, or in-cylinder), exhaust gas recirculation, or selective catalytic reduction.

Pre-2000 Engines. Under the 2008 Annex VI amendments, Tier I standards become applicable to existing engines installed on ships built between January 1, 1990, and December 31, 1999, with a displacement ≥ 90 liters per cylinder and rated output ≥ 5000 kW, subject to availability of approved engine upgrade kit.

Sulfur Content of Fuel Annex VI regulations include caps on sulfur content of fuel oil as a measure to control SOx emissions and, indirectly, PM emissions (there are no explicit PM emission limits). Special fuel quality provisions exist for SOx Emission Control Areas (SOx ECA or SECA). The sulfur limits and implementation dates are listed in Figure 8, below.

Figure 8. MARPOL Standards – Sulfur Limit in Fuel

| MARPOL Annex VI Fuel Sulfur Limits | | |
|---|--------|--------|
| | (%m/m) | |
| | SOxECA | GLOBAL |
| 2000 | 1.5% | 4.5% |
| 2010 | 1.0% | |
| 2012 | 0.1% | 3.5% |
| 2015 | | 0.5% |
| 2020 ^a | | |
| a - alternative date is 2025, to be decided by a review in 2018 | | |



MARPOL Annex VI Fuel Sulfur Limits

Heavy fuel oil (HFO) is allowed provided it meets the applicable sulfur limit (i.e., there is no mandate to use distillate fuels).

Alternative measures are also allowed (in the SO_x ECAs and globally) to reduce sulfur emissions, such as through the use of scrubbers. For example, in lieu of using the 1.5% S fuel in SO_x ECAs, ships can fit an exhaust gas cleaning system or use any other technological method to limit SO_x emissions to ≤ 6 g/kWh (as SO₂).

DOD Tests

The Naval Facilities Engineering Command conducted a three-year project, funded through the Environmental Security Technology Certification Program (ESTCP) to obtain air pollution emission factors for commonly used Department of Defense (DOD) diesel engines fueled with various types and blends of biodiesel [40].

The project included the measurement of the regulated air emissions of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), and particulate matter (PM).

For the project, five fuels were tested, a soy-based biodiesel, a baseline petroleum based ultra low sulfur diesel (ULSD), JP-8, and two yellow grease based biodiesel fuels (YGA and YGB). The biodiesel fuels were tested at the 20% (B20), 50% (B50), 70% (B70) and 100% (B100) concentration levels, with the biodiesel being mixed with the ULSD.

Ten types of DOD operated diesel engines were included in the test, including engines used for on-road, off-road, and portable power applications. Test engines were supplied by a

multitude of DOD facilities. Engines were selected for inclusion in the demonstration based on their widespread use within DOD.

This project focused on B20 biodiesel blends, since this is the blend of biodiesel used in military vehicles. The project results for the regulated emissions were that at the B20 level, there were no consistent trends over all applications tested. Within the context of the test matrix, no differences were found between the different YGA, YGB, and soy-based biodiesel feed stocks. The results of more extensive statistical analyses also indicated no statistically significant differences in CO, HC, NO_x and PM emissions between the B20-YGA and the ULSD. The tested NO_x reduction additives also proved to be ineffective.

Although these results were not expected, they were not considered a disappointment since the baseline USLD fuel proved to be greatly superior to existing on-road Diesel No. 2. The higher biodiesel blends (B50 to B100) were only tested on one Humvee, and with B100 on a 250 kW portable generator, and a single test on the Ford F9000 tractor. On the Humvee, the higher biodiesel blends did show a trend of higher CO and HC emissions and lower PM emissions.

VII. Conclusions

- Government mandates, directives and incentives at federal, state and local levels for use of biodiesel have largely driven the market for their use, and will continue to do so in the next several years.
- There are ASTM standards for certain blends of biodiesel but no specific U.S or International standards exist for use in *marine* applications.
- The characteristics of biodiesel potentially affecting safety in marine applications are of paramount concern. These concerns include inconsistent quality, lack of marine standards, and impact on fuel system components such as engine seals, engine manufacturer's warranties, disadvantageous hydrophilic properties, cold weather flow drawbacks, and the ability to remain stable in a marine environment over a period of time.
- Biodiesel fuel will eventually be incorporated into the main diesel fuel distribution systems, due mainly to government mandates, and problems can be expected in marine applications; similar to the introduction of ethanol into the fuel stream for gasoline powered boats.
- The largest segment of oceangoing ships in the U.S. is owned by the Military. Mandates and policies that pave the way for large scale marine use of biodiesel by the Navy and Coast Guard will also play a deciding role in establishing the supply chain and distribution systems for marine use biodiesel in the U.S.
- Until established standards are in place for oceangoing applications, state and local emissions standards create opportunities for biodiesel fuels to play a part in commercial marine applications for in-port use in auxiliary power and heating equipment.
- Biodiesel fuels contain less energy than petroleum diesel, resulting in increased fuel use. This affects vessel endurance and on-board storage capacity requirements.
- There are initial capital costs, such as for tank cleaning, involved with the use of biodiesel fuel for marine applications.
- In the U.S., recreational boat owners use about 136 million gallons of diesel fuel annually. Lower blends of biodiesel are being increasingly adopted by individuals for pleasure boating where locally cost-effective. They offer better lubricity, lesser odor, lesser eye irritation, and are environmentally safer.

- Biodiesel fuel should not be used for marine applications where the fuel cannot be used within eight (8) weeks unless long-term stability issues are addressed.
- Biodiesel fuel should not be used with tanks that can be ballasted due to the affinity to absorb moisture, and grow bacteria.
- Biocide treatment of commercial marine fuel should be applied whenever it is suspected that biofuel has been added to the fuel received for marine applications. However, there are no specific U.S and international standards for the use of biocides for biodiesel fuel for marine applications.
- Next generation biofuel sources and feedstock are being discovered to address the criticism that biofuel use will deplete food supplies without any reduction in the net carbon footprint. Examples of these are fast-growing plants such as switch grass, *salicornia* and *jatropha*. Algae has gained a foothold as the next generation biofuel
- Biodiesel fuels reduce most emissions relative to current high sulfur marine diesel, but nearly the same results can be achieved by changing to low sulfur or ultra low sulfur fuel.
- Fuel filter and associated maintenance costs related to the use of biodiesel for marine applications are high.
- Copper is not compatible with higher blends of biodiesel. Many inland and near-shore commercial vessels have copper fuel lines. This is a potential problem if biodiesel is introduced in the marine fuel supply system.

VIII. Recommendations

- MARAD, has a unique opportunity to lead the way in the standardization of biofuels for commercial marine use within the U.S. Towards that end; MARAD would be well-served to participate in international and U.S. forums to monitor international, military, and commercial fuel standards for acceptance of biodiesel into the main fuel stream. Continued work with the various inter-service committees and working groups on the impacts of biodiesel in combination with ULSD, with focus on marine engine performance and durability is a valuable endeavor.
- Look for opportunities with other government agencies such as Navy, Coast Guard, NOAA, Army Corps of Engineers and DLA, to participate in joint R&D of biodiesel blends for widespread marine use, with the goal of developing a universal **marine-use biodiesel specification**.
- The U.S. Navy, arguably the world's largest consumer of diesel fuel has embarked on an ambitious agenda to demonstrate a Green Strike Group by the year 2012 and regular "green" operations by 2016 using non-fossil fuels, including biodiesel. Sustainable marine use of biodiesel within the U.S. including establishment of biodiesel supply chains and viable price points will largely depend upon how well the Navy implements its plan. It would be beneficial to monitor of U.S. Navy-driven progress in the next two years in this regard, especially as it pertains to MARAD's Ready Reserve Force.
- If MARAD decides to use or specifies biodiesel blends over B5 for testing, R&D, or other marine use, it is recommended that it use only biodiesel purchased through DESC, or if a commercial open market purchase, the DESC purchase specification and clause should be invoked.
- MARAD should seek opportunities (collaborative or as sponsor) to conduct field-testing of biodiesel fuels on commercial vessels. Field testing will involve development of a cost and plan of action to conduct a one year, single vessel trial for marine use of biodiesel; to include baseline testing, fuel and maintenance monitoring including impact on filters, initial tank and fuel system cleaning, installation of shore side single purpose biodiesel fuel tank, refueling equipment and use of biocides.
- Biodiesel fuel should not be used in any vessels that have the capability to ballast fuel tanks with seawater or do not have the ability to strip water from the fuel storage tank bottoms.

- If future testing and R&D reveals a beneficial aspect to the use of bio diesel fuels, then MARAD could consider suggesting that future new vessel construction specifications include a requirement that fuel system components be compatible with biodiesel, and have segregated ballast tanks in large vessels.
- Develop an inexpensive field sampling and testing protocol to determine if biofuel has been introduced into ship-use fuel, to preempt being received on vessels in the future without adequate preparation. Current procedures require testing in laboratory conditions resulting in extended turn-around time.
- Conduct additional testing on marine engine emissions using biodiesel; compare the use of ULSD with biodiesel.
- Determine the extent of use of copper fuel systems in the commercial marine industry, and conduct testing to determine the severity of problems related to the use of biodiesel with copper fuel systems. Incompatibility has been verified between copper and biodiesel, but no research has been found to relate to the use of biodiesel and copper or copper-nickel, which is in common use for marine fuel systems.
- Monitor the marine insurance industry for institutional acceptance of biodiesel as a more environmentally-friendly alternative to marine grade diesels, resulting in premium credits and other incentives.

Abbreviations and Acronyms

| | |
|-----------------|---|
| AFV | Alternative Fuel Vehicle |
| ASTM | American Society for Testing and Materials |
| B100 | 100 percent biodiesel |
| B20 | 20 percent biodiesel, 80 percent petroleum diesel |
| BTU | British Thermal Unit |
| CFPP | Cold Filter Plug Point |
| CI | Compression Ignition |
| CO | Carbon Monoxide |
| CO ₂ | Carbon Dioxide |
| CONUS | Continental United States |
| DESC | Defense Energy Support Center |
| DLA | Defense Logistics Agency |
| DOE | U.S. Department of Energy |
| ECRA | Energy Conservation Reauthorization Act of 1998 |
| EPA | U.S. Environmental Protection Agency |
| EPAct | Energy Policy Act of 1992 |
| FAME | Fatty Acid Methyl Esters |
| F-76 | Fuel, Naval Distillate |
| GFI | Government Furnished Information |
| GVWR | Gross Vehicle Weight Rating |
| HC | Hydrocarbon |
| HUMBUGS | Hydrocarbon Utilizing Microorganisms |
| MGO | Commercial Marine Gas Oil |
| MSC | Military Sealift Command |
| MSDS | Material Safety Data Sheet |

| | |
|-----------------|---|
| MSHA | Department of Labor's Mining Safety Health Administration |
| NBB | National Biodiesel Board |
| NO _x | Nitrogen Oxides |
| NOLSC | Naval Logistics Support Center |
| NPAH | Nitrated Polyaromatic Hydrocarbons |
| NRL | Naval Research Laboratory |
| NREL | National Renewable Energy Laboratory |
| OEM | Original Equipment Manufacturer |
| OSHA | Occupational Safety and Health Administration |
| PAH | Polyaromatic Hydrocarbons |
| PM | Particulate Matter |
| PPM | Parts Per Million |
| RME | Rapeseed Methyl Ester |
| SE | Societas Europaea |
| SECNAV | Secretary of the Navy |
| SME | Soy Methyl Ester |
| SO ₂ | Sulfur Dioxide |
| ULSD | Ultra Low Sulfur Diesel |
| VOC | Volatile Organic Compound |

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PRIME, Inc. T/A Marine Innovations Designs And Solutions, Inc. (est. April 1995) is a Washington, DC area independent consulting firm completing *15 years* in the support of the U.S. maritime industry.

PRIME, Inc.'s team of engineers, scientists and program managers specialize in ship and marine related disciplines (design, construction, operations and disposal) and have performed numerous projects and studies in these areas for commercial clients as well as Government agencies such as the U.S. Navy (NAVSEA, NSWC), U.S. Coast Guard (HQ, R&D Center) and NASA. Reports and studies provided to these agencies have covered engineering design, open systems architectures, producibility, R&D, risk/hazard analysis, cost /affordability and acquisition support.

PRIME, Inc. has been a contractor for the U.S. Maritime Administration (MARAD) for the last 11 years and has provided a wide range of technical support to MARAD in the areas of ship emissions, economics, historical preservation, and retrofit analysis; and also performed fast-track special studies, such as the plan for the emergency closure of the MHI Shipyard in Quincy, MA.

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